Best practice regulations for solar thermal

ESTIF – European Solar Thermal Industry Federation
Renewable Energy House
Rue d'Arlon 63-65, B-1040 Bruxelles
Tel/Fax: 0032 2 54619 38/39
info@estif.org www.estif.org

Last update: August 2007

Intelligent Energy Europe

Table of Contents

1 Executive Summary

Regulations can be the single most important means to promote the use of solar thermal energy. Two main areas of action are needed:

1. Reducing administrative barriers
2. Enacting solar obligations for new buildings or those undergoing major renovation

Concerning administrative barriers: the general principle should be established that the use of solar collectors is allowed without the need of any special authorisation, except for a precisely defined and limited number of buildings of special historical interest. Moreover, it is necessary to make solar friendly the rules concerning the right of use of the roofs in large buildings with many residential or tertiary units.

Concerning solar obligations: the current trend in several European countries and regions is well justified by the manifold benefits of this instrument, which allows for the gradual preparation of the building stock in anticipation of the inevitable future scarcity of fossil fuels. Among other benefits, solar obligations create a minimal critical mass in the solar market and bring about economies of scale that also benefit the voluntary market in the majority of buildings that is not subject to the obligation. Moreover, solar obligations help solve the owner-tenant dilemma and send a strong signal to the users and to all professionals involved in the construction and heating sectors.

However, solar obligations fundamentally change the way the solar thermal market functions. Within a solar obligation, proper quality assurance measures must be foreseen, including quality parameters for the products, installation and maintenance, as well as a clear inspection and sanctioning regime. Without these measures, it is likely that some construction companies will install the cheapest products, thus producing less solar yield than desired. This could reduce the acceptance of the regulation and possibly of the solar technology in general.

This document offers for the first time a comprehensive analysis of the structure of solar obligations and proposes best-practice guidelines.

2 Introduction

This study is a tool to support the design of effective regulations to promote the use of solar thermal heating and cooling (ST) and to reduce administrative barriers, with the aim of helping policy makers at the local, regional, national and European levels to design policies most suitable to accelerate the growth of ST, as needed to reach the EU's binding target of a 20% renewable share by 2020.

The target public are legislators, public administration officials, energy agencies, NGOs, solar thermal associations, market actors and any person or institution involved in the design and implementation of regulations to promote renewable energy and energy efficiency associated with solar thermal issues. While the study has been developed with a European perspective, we believe that the analysis and guidelines developed here might also be helpful for debate outside the European Union, since the dynamic of ST market development is often similar.

Regulations are defined here as any kind of legislative or administrative rules affecting the growth of solar thermal, both positively and negatively, excluding those linked to financial incentives which are treated in a parallel publication produced within this project.

We do not aim to offer a compendium of all existing or thinkable regulations affecting ST, but to look in detail at selected issues most relevant for market development in Europe in the next years. The following issues are treated in this publication:

- Reduction of administrative barriers
- Solar obligations for new buildings or those undergoing major renovation

The study has been produced within the framework of the project *Key Issues for Renewable Heat in Europe* (K4RES-H), co-financed by the Intelligent Energy - Europe Programme of the European Commission and coordinated by ESTIF. Within this project, guidelines for best practice policies on different issues related to renewable heating and cooling are developed. Regulations are one of these key issues.

All project results about solar thermal, including all detailed case studies on which the present document is based, and the complete *Solar Thermal Action Plan for Europe,* can be found at:

www.estif.org/stap

The central project website is:

http://www.erec.org/50.0.html

There the parallel studies dedicated to geothermal and bioheat regulations can be found, as well as a number of other studies dedicated to solar thermal policies (financial incentives, policies for innovative applications) and summaries looking at renewable heating as a whole.

Many contributors have provided their knowledge and experience to the present study: the members of ESTIF and particularly the national solar thermal associations from nearly 15 European countries and also many other experts from energy agencies, public administrations, NGOs and others. We warmly thank each of them even though we do not have enough space to mention them all. A particular thanks goes to the main authors of this text, Raffaele Piria and Uwe Trenkner of ESTIF, as well as to Riccardo Battisti (Assolterm), Eddie bet Hazavdi (Ministry for National Infrastructure, Israel), Teun Bokhoven (Conergy), Jesus Ruiz Castellano and Amparo Fresneda (IDAE), Annalisa Corrado (Ministry for Environment, Italy), Jan-Olof Dalenbäck (Chalmers University), Xavier Dubuisson (XD Consulting), Will Foreman (Aperca), Rob Meesters (Solahart), Katja Mensing (Energie2000), Jan Erik Nielsen (SolarKey Int.), Thomas Pauschinger (Solites), Pascual Polo (ASIT), Toni Pujol (Barcelona Energy Agency), Robin Welling (TiSUN), Werner Weiss (AEE Intec), and William Gillett and Krzysztof Gierulski of the Executive Agency for Competitiveness and Innovation of the European Commission.

However, the final version of the document does not necessarily reflect the personal opinion of each of them. ESTIF remains solely responsible for the contents and any possible mistakes or omissions.

3 Reduction of administrative barriers

In large buildings with shared ownership, where many Europeans live and work, the **rules concerning the right of use of the roof** are in some countries unclear, or they make it very difficult to agree on the construction of a solar system, be it for collective use or for single apartments.
The public authority should enforce, or at least encourage as far as possible, easier procedures, for instance by inverting the burden of proof: stating the right in principle for any building owner to install a solar system on the roof, except other stakeholders can prove serious reasons against.

In some places **lengthy and difficult authorisations** are necessary, even to install small solar systems that are not much bigger and don’t look very different from an ordinary roof window.
This problem is mainly registered in very extensive areas of Italy, falling under a national regulation aiming among others at reducing the visual impact of new buildings or building elements. But problems are sometimes encountered also in modern buildings in areas without any special protection.
Some municipal authorities refuse authorisation to install solar collectors, simply because they would be visible from public areas. Sometimes, on the same or on surrounding buildings, a number of traditional TV antennas, satellite dishes, mobile phone masts and roof windows can be observed.
Esthetical opinions can hardly be discussed objectively. Of course, it must be possible to maintain the appearance of the roofs of medieval town halls or cathedrals. However, for a large part of buildings, authorisations procedures and practices should be adapted to the energy and climate policy priorities of the 21st century.
In certain cases, the local authority even requested a full Environmental Impact Evaluation for very small (2-4 m^2) solar systems: the cost of the EIA would be several times higher than the cost of the system itself, and this for a technology producing clean solar energy and known for its minimal environmental impact!

The sheer need of an authorisation is often enough to discourage potential users of solar energy: the right timing (for instance replacement of the heating system) may be short. And there may be a disproportion between the low cost of the solar system and the effort needed to obtain the authorisation.
The **general principle should be established that the use of solar collectors is allowed without the need of any special authorisation**, except for a precisely defined and limited number of buildings with particular historical or esthetical value. And in these areas, the procedures should be quick and transparent: the public authority should provide a list of acceptable technical solutions for the integration of solar collectors, that should be applicable for as many listed buildings as possible.

4 Solar obligations

Solar obligations are regulations requiring a minimum share of the heating demand be covered by solar energy. Most refer only to the domestic hot water demand and prescribe a minimal solar share ranging from 30% to 70%. Currently, in Germany, renewable obligations are being discussed that would prescribe a minimal share of 10-20% of the total heating consumption, including space heating. They usually apply to new buildings, those undergoing major renovation and sometimes in the case of replacement of the heating system. Often, they are in fact renewable heat obligations, as the legal requirement can be fulfilled also with other renewable heating sources.

A decade ago, the idea of making the use of solar or renewable energy compulsory sounded radical and politically unfeasible in most parts of the world. Currently, solar obligations have been adopted or are being discussed in a number of countries, regions and municipalities in Europe and beyond.

Security of energy supply and climate change have become top political priorities. Together with energy efficiency, renewables are the only sustainable answer to both problems. Within the renewable energy policy debate, the heating and cooling sector are now fully integrated in the European agenda, after having been neglected for over a decade. The solar industry has grown and a new generation of higly reliable products is on the market.

"The decision by Fingal County Council to specify the highest standards of energy efficiency for building in three local area plans is one of the most significant developments in building for decades. For the first time a local authority sees the wisdom of ensuring that buildings are designed to the highest standards in energy efficiency. This will result in warmer, more comfortable buildings that are healthier to live in and much cheaper to run. I hope this ground-breaking initiative by Fingal County Council will set the standard for developments in Ireland. We don't really need pilot schemes or one-offs, the technology has been proven to work, so these standards can be met, we know that. It will work",

Gerry McCaughey, CEO of Century Homes (now Kingspan Century),. Europe's largest timber frame home manufacturer

Solar obligations are probably the single most powerful instrument for promoting the use of renewables in new buildings. However, they do not cover a large part of the potential uses of solar thermal, like space heating and cooling, industrial processes, water desalination, as well as existing buildings that are not undergoing major renovation. While indirect positive effects of solar obligations on these areas can be expected, flanking measures focused on the voluntary market are necessary, like financial incentives and awareness raising, and training.

To our knowledge, no analytical and comparative literature on solar obligation exists. This is the first attempt to give a systematic overview and suggest guidelines based on the available experience and on the knowledge of the industry about solar thermal market development in general. Given the pioneering nature of this exercise, the authors would very much welcome any critical comments and new information, that will be taken into account in future updates.

The history, analysis and guidelines offered here are based among others on a number of case studies reported in the annex.

4.1 A short history of solar obligations

The first solar thermal obligation was enacted in Israel in 1980, as an answer to the worries about security of energy supply in the aftermath of the second oil crisis. Despite its success (see annex), it took two decades before the next one was adopted in Barcelona. During the 1980s and 1990s, renewables were not high on the agenda, as energy prices went down and the increasing evidence about climate change unfortunately did not lead to adequate political reaction. At the same time, the solar thermal industry in Europe was not yet developed and active as in more recent years.

4.1.1 From Barcelona to the Spanish model

The first discussion on a solar obligation in Europe started in the city of Berlin in the 1980s. An advanced draft law had been developed, but Berlin finally failed to adopt the obligation, due to a change in the government and to the opposition of the local construction industry.

However, this process helped to stimulate the debate in the City Council of Barcelona, that in 1999 adopted its solar obligation which then entered into force in 2000. The "Barcelona model" (see annex) came from a city with strong charisma, and at the right time: rising energy prices and worries about the security of energy supply and climate change created a receptive political environment. The solar thermal industry had grown and a new generation of reliable products was on the market.

However, even the friends of solar energy were surprised by the speed with which solar obligations spread through Spain and in other European countries. Solar obligations are now in force in more than 50 Spanish municipalities, including large cities like Madrid (see annex) and Sevilla, and covering more than half of the population in Catalonia.

Obligations were adopted by local governments of different political colours. The broad political consensus lead to the inclusion of a solar obligation in the new National Building Code (see annex), that was to a large extent developed by the previous conservative administration, and was tightened and finally adopted in 2006 under the current socialist government. In the same year, Barcelona City Council adopted a revised version (see annex) of its municipal obligation that enlarged the number of obliged buildings, increased the share of solar energy required and tightened the quality assurance measures.

Six years after the "Barcelona model" was launched, solar obligations have stood the first test of time, as shown by the support of different political parties throughout the country by their first significant results in terms of energy savings and improved market conditions, and by their capacity to evolve and improve their details.

4.1.2 The debate at European level and beyond

At the end of June 2007, solar or renewable heat obligations were in force or in advanced state of discussion in a growing number of European countries, regions and cities. These include Portugal, Italy (several municipalities including Rome, two regions and at national level – see annex), Germany, (the town of Vellmar, the Federal State of Baden-Württemberg and possibly at federal level - see annex), the region of Wallonia in Belgium, some Irish counties (see annex) and a number of UK local authorities that followed the example of the London borough of Merton. This list may not be exhaustive, as the number of local initiatives is constantly growing.

At EU level, the decision of the 27 Heads of State in March 2007 to set a binding 20% target for the renewable share of total energy consumption by 2020 is creating a strong pressure to implement more effective policies able to deliver the necessary growth rates throughout Europe.

Currently, the European Commission is preparing the proposal for a new Directive that will cover all renewable energies. For the first time, this Directive will also cover the heating and cooling sector. It is not yet known which specific measures will be included in the proposal, that must then be adopted by the European Council and the European Parliament.

The latter is very likely to send a strong message in favour of solar obligations: on 9th July 2007, its competent ITRE Committee adopted almost unanimously an amendment calling for "the Commission to speed up the widespread adoption in all Member States of best practice regulations making it compulsory, at least in the case of major renovation of buildings and new buildings, for a minimum proportion of the heating requirement to be met from renewable sources as has already been implemented in a growing number of regions and municipalities". Given the large support received in ITRE, it is likely that this text will be adopted by the plenary of the European Parliament in September 2007, giving a strong signal to include renewable heat obligations in the new European Directive.

However, the main responsibility for the design, implementation and enforcement of solar obligations will remain with the national or local authorities which have the competence for building regulations. For them, there is no reason to wait for the EU Directive to be adopted. The sooner they are in force, the stronger their benefits.

The idea of renewable heat or solar obligations is gaining ground also outside of Europe. In June 2007, speakers at the *estec2007* (European Solar Thermal Energy Conference) reported that solar obligations are being discussed in the Tokyo Metropolitan Area (35 millions inhabitants) and in Minas Gerais, the second most populous Federal State in Brazil, while some Australian Federal States have enacted regulations that make solar thermal one of the favourite options to meet the required efficiency standards. According to representatives of the Chinese Renewable Energy Industries Association, a discussion on solar obligation is also progressing in China.

4.2 Benefits and costs of solar obligations

Beyond the available empirical evidence (see annex), this part of the document is based on qualitative analysis, arguments and opinions of experts from the solar and construction industries, local and national governments and energy agencies.

With the notable exceptions of Israel's success story and partly of Barcelona, the existing solar obligations are too recent to allow for a systematic empirical analysis of their impact. This is due to the physiological delay of some years between the adoption of a solar obligation, the time when the systems are effectively installed, and the time when an empirical study of their impact becomes possible.

It must be noted that, in general, the cost and benefits of building practice and regulations are difficult to be empirically quantified. Economic factors are intertwined with historical and cultural heritages. The level of formal and factual compliance with any kind of building regulations varies strongly among different countries, regions and also among different kind of buildings. This is linked to the important role played by the informal economy, particularly in the renovation works and in small residential buildings. Also the ways in which building regulations are enforced by the public authorities vary strongly. In different contexts, the same rule can lead to different and even contradictory results.

4.2.1 Justification and benefits

The long term begins today

The logic of the financial markets implies that buildings are planned with an investment horizon of a few decades, though experience shows that many last longer. Taking into account the amounts of energy needed to construct buildings, it is reasonable to assume that by the second half of the 21st century there will be an increased interest for building conservation, which is not yet reflected in the economic rationale of building developers today. Many future new buildings will last into the 22nd century. By then, fossil fuels used for heating will be very scarce and expensive. They will probably still be irreplaceable in sectors like air transport and chemicals. One more reason to accelerate the necessary transition: in the long term, 100% of the energy needs of buildings have to be covered by renewables.

Buildings are key to any comprehensive energy policy strategy. 40% of the EU's energy consumption originate there, and heating has the lion's share. At the EU and national levels, legislation has been adopted to improve the energy performance of buildings. However, in most EU countries, this legislation is mainly promoting energy savings measures. Higher energy efficiency is necessary and urgent, but alone will not be enough to keep houses and people warm. Particularly for domestic hot water, energy must be consumed and solar can contribute strongly.

Promoting renewable heating through financial incentives taken from the public budget becomes more and more difficult as the market volumes increase. A key advantage of solar obligations is that they have a very limited impact on public budgets (see below). The main costs are carried by the building developers or owners. If the certification of the energy performance of buildings works correctly, the owners will be able to pass the costs on the building users, who also benefit from the reduced energy bill allowed by a solar system.

Adapting the building stock will be a steady process. At least new buildings, and those undergoing major renovations, should be adapted to future conditions.

A solar (or renewable heat) obligation helps gradually prepare the building stock for the post-oil and gas era.

Quantification of the aggregated energy savings

The aggregated energy savings triggered by a solar obligation are a function of manifold factors, among them:

- The number of buildings subject to the obligation, depending on its detailed provisions and enforcement (including the exemptions)
- The number and types of new buildings in a country, region or city
- The specific requirement concerning the share of solar energy to be achieved
- The quality of the solar products, their installation and maintenance
- The behavioural patterns of the users, mainly the volume and timing of domestic hot water usage
- The intensity of the positive effects of the obligation on the voluntary market, i.e. the installation of larger solar system than required, and the increase of solar energy use in buildings not subject to the obligation

A precise quantification would require complex assumptions and modelling, and would have a wide margin of error, especially considering the little empirical data available so far. This exercise was not possible here. However, it may be useful to consider some data that can contribute to a rough estimation.
Domestic hot water contributes roughly 2% of the final energy consumption in the European Union, i.e. equivalent to circa 24 million tons of oil per year. If all buildings covered 50% of their hot water demand with solar energy, the savings would be around 12 mtoe per year. This is equivalent to the total consumption for hot water and space heating of almost 10 million European households.
Taking into account that roughly one third of domestic hot water is currently produced with electricity, the gains in term of primary energy are substantially higher. Of course, depending also on other support measures and on energy prices, it will take a shorter or longer time to cover all buildings, but on the other hand a solar obligation also encourages the voluntary solar market beyond the legal requirement.

If European would cover 50% of its hot water consumption with solar, the savings would be roughly 12 mtoe per year, or 1% of the EU's final energy consumption. This is equivalent to the total consumption for space and water heating of almost 10 millions households.

Seize the opportunity when it comes

Installing a solar system implies works on the roof, piping through walls and finding the place for the hot water tank inside the building, if it is not installed on the roof. All this is easier, cheaper and often more effective if the solar system is included from the earliest stage of planning of a new building.
In existing buildings, there are short windows of opportunities when the installation of the system is usually most convenient, mainly when the (water) heating system and/or the roof are being changed anyway.

Once these opportunities (new built, refurbishment) are missed, the installation of a solar thermal system is usually technically possible, but economically less interesting. One has to take into account not only the direct financial cost of the works, but also the time and effort needed to commission them, as well as the disturbance caused to those living or working in the building.

It is most convenient to include solar at an early stage of planning in new buildings or when a new heating system is being installed in existing buildings. A solar obligation makes sure that these convenient opportunities are not missed.

Tackling the tenant-owner dilemma

Nearly 100% of the costs of a solar system are upfront investment costs, whereas the benefits in terms of energy savings are spread on 20 to 25 years lifetime. This is a major barrier to the use of solar, as most investors look at a shorter time horizon.

In case of rented buildings, the running fuel costs are paid by the tenants, while the investment is paid by the owner. This creates a powerful negative incentive against renewable energies or efficiency measures.

A good step towards reducing this problem is the certification of the energy performance of buildings, introduced by the European Directive on the Energy Performance of Buildings. However, this is being implemented in different ways, and not everywhere the certificates will offer complete information to those buying or renting a building. Moreover, more transparent information is not enough to completely tackle the perverse incentive mentioned above: as long as the use of renewables is not widely spread, buyers and tenants may still face little choice than accepting what offered by the market.

A solar obligation makes sure that renewables are used also when the energy bill is paid by tenants, who cannot decide on structural investments.

Economies of scale through critical mass

Solar obligations create a predictable market for solar or other renewable heating technologies. Different than financial incentives, which often change according to the availability of public budgets, solar obligations are believed to be a rather stable form of support, less prone to unexpected changes.

In such a more stable environment, the whole supply chain is encouraged to invest in the long-term development of the market. In manufacturing, the sheer approval of the Spanish CTE has contributed to trigger substantial investments to expand production lines all over Europe. These investments will benefit the buyers of solar equipment also outside of Spain.
However, the economies of scale in the manufacturing process, are only a part of the benefit of creating a critical mass of the market. On average, more than half of the turnover linked to solar thermal is due to services like system design, marketing and sales, installation and after-sale service. These services are inherently local and benefit the regional economy: solar thermal replaces imported fuels with local jobs.

Within the area of application of an obligation, investments are triggered to expand the distribution networks, to train installers and engineers, and on marketing. These investments contribute to build up the critical mass on the supply-side that is needed to address wider groups of potential users. These investments tend to reduce costs in the medium term and increase the use of solar thermal also in the large number of buildings that are not subject to the obligation: the voluntary market benefits from a broad availability of trained installers and heating engineers, architects gain experience in the integration of solar, and potential users become exposed to spontaneous mouth-to-mouth propaganda.

These effects can make the solar thermal market largely self-sustaining in the medium term, as shown by over two decades of experience in the development of solar thermal in different countries. Comparing Greece with Sicily, or Austria with similar countries, one sees that the same level of public support produces massively higher effects where the market has already reached a significant dimension. Thanks to the strong support in past decades, Greece is one of the leading markets in Europe with hardly any subsidy.

By creating a stable market in a small part of the buildings, solar obligations trigger investments in the whole supply chain, leading to economies of scale and higher use of solar energy.

Positive side effects on the voluntary market

In most cases, solar obligations apply only to new buildings and those undergoing major renovation. By its nature, an obligation covering a large number of buildings can only be based on a minimum common denominator. Therefore, obligations usually require a small share use of solar energy, widely below the technical potential of many obliged buildings.

It is therefore important that solar thermal continues to grow also in the voluntary market, i.e.:

- The use of solar in buildings not subject to the obligation
- A higher solar coverage then required in buildings subject to the obligation

The arguments above suggest that a solar obligation can have positive side effects on the voluntary market by enhancing awareness among potential users and investors, by increasing the availability of trained installers, engineers and architects, by strengthening the offer of solar thermal systems and by creating economies of scales and thus cost reductions.
27 years of experience in Israel and first hand industry feedback from Barcelona and other localities in Spain (see annex) empirically confirm this positive side-effect.

In the long term, this may become the most important effect of a solar or renewable heat obligation, particularly with regards to the voluntary use of more solar energy than strictly required.

Obligations encourage the voluntary use of solar energy beyond the amounts required by law, and in buildings not subject to the obligation.

4.2.2 Costs

Most of the costs caused by a solar obligation are borne directly by the building owners, or charged to them by the constructors. The effect on the public budget is limited to the enforcement procedures and to the specific costs on publicly owned buildings.

Costs carried by the building owner

The additional costs of installing solar have to be balanced with the financial benefit in terms of reduced energy consumption during the lifetime of the system, which is typically 20 to 25 years.
When calculating the break-even point for solar thermal systems, the main variable is the future price of oil, gas, electricity or biomass, the energy sources replaced by solar. Most analysts assume that their price will continue to grow substantially during the next decades. However, in their daily decisions, many people still tend to calculate break-even based on constant energy prices. This gap between information and behaviour is one key rationale for solar obligations.

At current energy prices, the break-even point of small solar thermal systems typically required by solar obligations is in most cases within the lifetime of the system.

To cover more than 50% of the domestic hot water demand in a one family house, the total costs of a solar system are currently in the range of 700-4000 EUR. The variation is a function of the available solar radiation, of the kind of building and heating system, of the local labour costs and of the quality of the solar products used. The specific costs are significantly lower for large buildings with central heating systems, and of course for large orders related to many small houses. There is a significant potential for economies of scale.

The cost of the solar obligation as a share of the final price of a new building depends on the general costs of the building and of the ground in each specific location. According to first provisional estimates of the Spanish Solar Thermal Industry Association (ASIT), in most Spanish regions the implementation of the CTE is increasing the total costs of the building by clearly less than 1%, and this share is most likely to go down significantly once the construction companies have become used to regularly dealing with this technology. This level of additional cost is unlikely to create significant disincentives to the construction of new buildings.

Costs carried by the public administration

Compared with other support measures for solar thermal, like financial incentives, obligations cost very little to the public budget.

Enforcing the obligation implies some administrative tasks. Their intensity and costs depend mainly on the chosen monitoring and sanctioning procedures.

The check on the plans previous to the authorisation of the building adds very little to the numerous other checks usually performed by the administration. The same is valid for the checks after construction before the building is commissioned.

If it is chosen, as recommended below, to control ex-post the functioning of a sample of the solar systems installed, some additional costs arise. In order to provide valuable information, such monitoring must be performed by trained personnel with good knowledge of solar thermal heating systems.

The additional costs for monitoring can be kept to a minimum if the sanctioning regime for those responsible for possible malfunctioning is clear, strict and credible. If so, a small number of sample controls will be a sufficient incentive for most installers, solar and construction companies to deliver state-of-the-art installation (see below more details).

The additional cost for controlling must be balanced with the progress in technology, system design and building integration that can be triggered by the knowledge created through the controlling process, if its results are made available to the sector.

4.3 The need for quality assurance measures

"Another impression … is the low level of interest the (building) developers have in the quality of the equipment, and their high interest in getting over the new administrative hurdle as cheaply as possible" (page 34 of the K4RES-H case study done by the national Spanish energy agency IDAE, about the Madrid solar obligation, see annex).

The introduction of a solar obligation fundamentally changes the way the solar thermal market functions. Above we have discussed many positive aspects of this change. However, it also entails a danger: without appropriate quality assurance measures, low quality solar installations may occur frequently, leading to a loss of solar energy gains and to a reduced acceptance of the obligation itself and of the solar technology in general.

In an obliged market, if users are unhappy with the functioning of the solar systems, they will tend to react more negatively than in a voluntary market. The construction companies responsible for the choice of the products and their installation will answer that they simply fulfilled a regulation. Therefore, the regulations must be designed in a way to make sure that products, planning, installation and maintenance of the system are state-of-the-art.

4.3.1 Economic interest, behaviour and knowledge

In the **voluntary market**, those who order a solar system have their own motivation to have it working properly, in order to reduce their conventional energy bill, increase their independence and the immaterial value of using clean energy. In most cases, they live or work in the building and they will also use the system. Also in the case of rented buildings where the users are the tenants, if the owner decides to go solar, a special interest from his side can be assumed.
In the voluntary market, the buyer determines the desired level of quality, chooses the product, the installer, and usually can choose to take a maintenance contract or additional warranty. If something goes wrong, the user knows who is to blame. The continuous growth of solar thermal, particularly in those countries and regions where the level of penetration allows for a strong level of mouth-to-mouth propaganda, demonstrates that most users are satisfied.

An **obliged market** is substantially different. The solar systems are generally ordered by construction companies that may have little or no motivation to choose products and services of a quality higher than strictly required by the wording of the regulation. Once the building is sold or rented, they do not benefit from the energy savings. Their main interest is to keep down the investment costs, like for all other building components.

During the first few years of implementation of an obligation, there may be a lack of well qualified engineers & installers, a lack of integration in the mainstream HVAC construction processes and an insufficient knowledge of the technology among architects and construction industry managers.
Also, the users have to be educated. Particularly in countries with a high share of large residential buildings for rent (like Spain), some users may not even become aware that a solar system exists. Most of the users will have very little knowledge about solar. This can lead to false expectations and to a limited capacity to identify and understand even simple faults in the installation or in the operation of the systems.
Some users may be obstructive and tend to carefully check and protest at any sign of reduced performance.
Finally, the skilled solar companies may not be able to satisfy the strong increase in demand triggered by the obligation. New market players with little or no reputation to lose may enter the market and try to make quick money, thereby compromising the reputation of the serious solar companies.

Most of these are problems that a solar obligation will help to solve. But, especially in the first years, some teething troubles are possible.

4.3.2 Quality features of solar thermal systems

Solar thermal systems do not constitute any relevant health or safety risk for the users, nor for craftsmen with a basic training. Also, a loss of comfort caused by the solar system is nearly impossible, since there usually is an auxiliary heating source (gas, oil, biomass, heat pump or electricity) that guarantees availability of hot water or space heating when the solar input is not sufficient.

The quality concerns refer only to the functionality of the system, i.e. to their durability and the solar energy output.

The existence of the auxiliary system implies that the user does not always perceive if the solar system is working perfectly: hot water is there anyway. Underperformance can often be detected only if function control procedures and/or devices are in place.

In the case of **medium or large sized systems**, particularly those also supporting space heating, it is normal practice to install controllers and devices monitoring the system. In some cases, a reduction of solar output can be solved by very simple measures like cleaning the collector surface. In other cases, it is necessary to ask for qualified assistance.
For very large systems, remote monitoring is a standard feature: the system provider or another specialised company receives data from the monitoring devices and software automatically identifies anomalies, often before the user notices them. The monitoring company may be able to remotely intervene on some valves, reducing to a minimum the need for local intervention. This kind of service can be combined with a guaranteed solar result contract or similar, provided by an energy service company.

For large systems, it is therefore important that a solar obligation prescribe that current best-practice monitoring is applied, including a service contract. Monitoring devices and procedures, as well as regular maintenance must be considered as an integral part of the investment in the solar system. Guaranteed solar result contracts should be encouraged, particularly for very large systems, but the offer is not yet developed enough for them to be made compulsory.

However, many **small systems** currently on the market only have rudimentary measuring devices, or none at all. In particular, natural flow systems, which do not need a controller and can cost very little, often come without any monitoring.
This may be rational, as the cost of advanced monitoring devices may not be justified by their practical benefits. In fact, a complete fault of the system can be easily detected even without any monitoring device, by switching off the auxiliary heater, using all the hot water in the tank, and then seeing whether the fresh water has become hot at the end of a sunny day. However, even with a monitoring device, it may not be easy to determine the existence and extent of partial system failures, as their effects are intertwined with several other factors, like variations of solar radiation and external air temperature, and of consumption patterns.
Like for many other relatively cheap household appliances, when underperformance is presumed in a small solar system, it is not always easy to determine its cause and take consequent measures, taking into account that the low purchase cost of small solar systems may not justify overly expensive diagnosis and repair.

For these reasons, in the voluntary market many providers and buyers of small solar systems have so far been happy with or without rudimentary monitoring devices and procedures.

Detailed quality assurance measures for large and small systems are proposed in the annex.

The issues mentioned above should not give the impression that solar systems are particularly prone to failure. The broad majority of solar systems work to the full satisfaction of their users. And there are hardly any household appliances offering the possibility of monitoring or assessing their actual energy consumption.

Most regulatory obligations in the building sector have implementation rates below 100%. For instance, fire extinguishers and detection systems are not always installed and maintained according to law. This does not mean that the rules are useless. One would rather conclude that appropriate monitoring and sanctioning procedures should be enforced to increase the rate of implementation to an economic optimum.

From an aggregated, political point of view, even if the share of the properly working systems does not reach 100%, the amounts of solar energy produced by the majority of well working systems are large enough to justify the obligation and other support measures. However, this is of course no argument from the perspective of the individual users affected by the failures. If people are obliged to purchase a product because it saves energy, appropriate quality assurance measures are necessary to guarantee a long-term acceptance of the regulation.

4.3.3 Recommended quality assurance measures

Due to their technicality, some details are in Annex 6. Here only the general principles are discussed.

The purpose of the quality assurance measures should be to ensure that the cheapest possible solution fulfilling the wording of the obligation will provide convenient solar energy for a long time.

Quality assurance measures should cover the following areas:

- Components and system configurations
- Installation works, guarantee and after sale service
- Function control
- Third party monitoring of a sample of the systems installed

A clear sanctioning regime is necessary to give a reasonable incentive to the market actors to comply with these measures.

Components and system configuration

The main features to be taken in consideration are the performance, durability and safety of the components and of the system configuration.

These features are covered by existing European standards for solar collectors (EN 12975) and for factory made systems, i.e. kits including all components that only have to be assembled on the spot (EN 12976).
For custom made systems, a EN standard is in advanced phase of development. All large solar systems are custom made.

Solar collectors: Keymark should be required

Within solar obligations, due to the enhanced quality needs discussed above, ESTIF strongly recommends always requiring a Solar Keymark certification for the solar collector.

The Keymark is a voluntary third-party European certification mark, developed by CEN (European Committee for Standardization). The Solar Keymark has been developed by ESTIF, with support of the European Commission. It certifies compliance with one of the two standards mentioned above[1]. It offers higher benefits reliability than ordinary EN test certificates: the user can be ensured that the Keymarked products sold are equal to those tested, because the latter are randomly taken from the production line by inspectors from accredited test institutes. Furthermore, the Keymark requires the existence of a quality management system comparable to ISO 9000.

A wide range of information on the Solar Keymark is publicly available at www.estif.org/solarkeymark

A few years after its introduction (last update: July 2007), over 160 collector models from more than 80 suppliers bear the Solar Keymark. These collectors represent probably more than 70% of the sales in Europe. The number is increasing every month. Since 2007, the German government has required the Keymark as a condition to be eligible for the federal financial incentive. In the context of an obligation, there is no reason not to request this state-of-the-art certification of the collector.

System certification and quality assurance

For factory made systems, at the moment of writing (last update: July 2007), only seven systems from five suppliers bear the Solar Keymark, also due to overly complex certification procedures that will probably be simplified soon. ESTIF is working in this direction with the support of the Solar Keymark-II project, co-financed by the Intelligent Energy Europe Programme of the European Commission. For custom made systems, the EN standard is in advanced state of development.

Therefore, it would be too early to require a Keymark system certification as the only possibility.

ESTIF recommends that any solar obligation accept a Keymark system certification if available. In the annex, we recommend a set of additional and alternative criteria regarding the system configuration and design. Their purpose is to guarantee that the quality and relative sizing of a few key components are reasonable.

Avoid barriers to trade!

It is absolutely necessary to avoid the creation of artificial barriers to trade within the European market. Only within an open and large European market can the manufacturers of solar thermal products achieve the economies of scale needed to reduce costs.

[1] If the collector is only sold as part of a Keymark certified system (EN12976), a Keymark for the collector alone is not necessary, as the Keymark system certification assures that the collector fulfils the requirements of EN12975 - except for specific information on collector performance figures.

Therefore, ESTIF strongly urges the national or local authorities designing support measures, including solar obligations, to avoid setting product requirements not strictly based on existing European standards and certification schemes. If additional or divergent requirements are created, the markets become fragmented, the competition is reduced, the certification costs increase and in the end the users lose in terms of choice, quality and prices.
European standards and certification procedures can and should be constantly improved. Any new ideas or national input to the European co-operation is welcome if it aims at improving the European norms and is discussed collectively at European level. Instead, additional national requirements or certification procedures only damage the growth of solar energy.

Installation works, guarantee and after sale service

The quality of the installation is essential for the correct functioning of a solar system. Installation mistakes are the most frequent cause of failures.
The industry is developing more and more kit solutions, thus strongly reducing the complexity of the installation and the possible mistakes. However, some specific know-how is necessary, particularly for large systems.
Therefore, a solar obligation must contain requirements for the qualification of the installers. The installion company should be obliged to sign a commissioning check list, to supply a minimum guarantee and after sale service, and to provide the user with the necessary information about the system.
The installing company should be obliged to repair relevant system failures and, if needed, get assistance from the manufacturer. The user should have only one contact company responsible for the functioning of the whole system.

In the annex, more detailed recommendations are provided. However, the context in the different EU countries is very heterogeneous, for instance with regards to the general level of training of the professionals involved in the building sector, the general rate of compliance with regulations, the typical relationships between building developers, subcontractors, owners and users. Specific solutions must be tailored at national or regional level.

Function control

For small systems, a solar obligation should ensure that it is possible for the user or the installer to check if the system is operating and delivering heat.
The user manual should clearly describe how to perform a simple check of the system and list the simple maintenance operations that do not require special skills.
Within a solar obligation, it is reasonable to require the installation of a monitoring device, if its cost is not higher than the value of the energy savings in a half year of system operation. If the cost is higher, the added value of the monitoring device is disputable. It must be noted that this requirement should not apply to the voluntary market, where the user should be free to choose the desired level of monitoring.

For larger systems, more sophisticated measuring and monitoring devices should be required, and the user manual should clearly explain how to interpret the information provided by the device and how to perform the maintenance and checks that do not require special skills.

The purpose of such function control features is on one hand to inform and empower the users and on the other hand to create an incentive for the installing companies and the hardware suppliers to deliver state-of-the-art products and services, in their own interest of reducing the costs of after sale interventions.

Third party inspections of a sample of systems

Foreseeing a scheme of third party inspections is recommended.

After one or two years of operation, a random sample of the systems installed under the obligation could be inspected by qualified third party experts. The experts should have access to any stored data about the operation of the system, and to the physical installation. In case malfunctioning is ascertained, the public authority should have the means to force the installing company to repair or improve the system.

In some countries, regular inspections are foreseen for *all* heating systems, with the aim of controlling their emissions. In these cases, the number of solar systems inspected could be increased, though it must be considered that the inspectors should have specific solar skills.

An analogous inspection scheme has been implemented in France, within the QUALISOL scheme of certification for solar installers. After having followed the training, the certified installers know that some of the systems they install may be checked by an expert. In case of repeated quality problems, the sanction faced by the installer is the withdrawal of its QUALISOL certification, leading the installer out of the solar market, since the use of a QUALISOL certified installer is a precondition for receiving a financial incentive.

At least in anonymous form, the data about the operation of the systems should be made available to the interested public. This could create a broad pool of knowledge, useful to further improve the quality of products, system design and installation procedures. Moreover, consideration could be given to enacting a name and shame system, i.e. publishing the names of the installation companies, and of the manufacturers in case of repeated failures. This would create a powerful incentive for the companies to provide high quality products and services.

Inspections should be applied more frequently to large systems, as the larger solar energy production and costs justify more attention, but a few small systems should also be inspected to make sure there is a strong incentive for quality installations in this market segment too.

4.4 Structure for a solar obligation and guidelines

This section analysis the structure of solar or renewable heat obligations, looking at each of their main components:

- Buildings subject to the obligation, exceptions
- Definition of the required solar contribution
- Solar or renewable heat obligations
- Technical parameters for the calculation of the fulfilment
- Definition of the accountable persons
- Control procedures
- Sanctioning regime

Some guidelines are proposed. However, it is very difficult to provide general guidelines applicable to the whole European Union, as the context in the different countries is very heterogeneous in terms of the building stock, the prevailing heating systems, the regulatory and legal background, the market penetration and potential of the different renewable energy sources, the typical training level of installers etc.

Therefore, the guidelines proposed here are of a general nature. Their implementation should always be carefully analysed taking into account national or local conditions.

It must be noted that, on the demand side, the difference in climatic conditions is not very relevant, because the demand for domestic hot water varies only slightly between the North and the South. However, of course, Southern Europe has a stronger potential for cheap solar energy, whereas in Scandinavia biomass is often more convenient than in the South, and obligations may take this into account.

4.4.1 Buildings subject to the obligation, exceptions

When do obligations apply

All new buildings and those undergoing major renovations should be covered by a solar obligation. In these cases, the benefits are obvious and the additional costs caused by the obligation nearly negligible.

A draft law proposed by the government of the German Federal State of Baden-Württemberg foresees a renewable heat obligation also in the case of replacement of the heating system. The same is being discussed in Germany at the federal level. The advantage is that installing renewable heat components is usually cheaper when this event occurs. Once the replacement has been done, the window of opportunity is closed for one or two decades.

Concerns have been expressed that such a provision might encourage the building owners to postpone the replacement of old gas or oil burners with more efficient condensing boilers. However, this negative incentive is limited in time, because the replacement must occur anyway sooner or later, and can be reduced with a specially designed financial incentive. Moreover, in some countries like Germany there already is an obligation to replace very old and inefficient boilers.
Therefore, ESTIF recommends considering applying solar or renewable heat obligations also in the event of replacement of the heating system, at least in the numerous countries where condensing boilers already have reached a high market penetration.

In which buildings do obligations apply

In Spain, solar obligations apply to nearly all kinds of building uses. In some other countries or regions, applying obligations only to the residential sector is being discussed. From the point of view of energy savings, the latter is not recommendable, because many tertiary buildings (hotels, collective residences for elderly people, hospitals, barracks, swimming pools, sport facilities, large refectories etc.) consume a lot of hot water and offer very good conditions for solar heating or other renewables. Of course, some tertiary buildings consume very little hot water. To take this into account, it is possible to exempt buildings with no or very small consumption, though it must be noted that the City of Barcelona, after some years of experience, decided to abolish this exemption (see annex).
For temporarily used buildings, like holiday houses, exceptions can be foreseen, as in the case of the Spanish CTE.

Exemptions

One of the most frequent exemptions foreseen by existing solar obligations concerns the protection of historic buildings; of course, solar collectors must not necessarily be installed on the historical roofs of the medieval town-hall or cathedral. However, particularly in areas with a large number of listed buildings or with lengthy authorisation procedures, this exemption should be formulated and implemented wisely: antennas and roof windows, which look very similar to some solar collectors, have become ordinary building elements in many historical centres.
Solar energy should not be discriminated against. For instance, in a draft municipal obligation discussed in a large Italian city, a clause foresaw that solar collectors should not be visible from the street level. This would completely exclude solutions based on façade collectors that can be perfectly integrated in glass facades of modern buildings.

And why should solar collectors be hidden? In some neighbouring countries home owners show them proudly, and this contributes to their dissemination. It may be sensible to adapt esthetical conceptions to the upcoming post-oil era, especially considering that a glance over the roofs of the wonderful historic centre of that city is enough to see hundreds of traditional TV antennas, satellite dishes, mobile phone masts and roof windows.

Other frequent exceptions to solar obligations refer to buildings where other renewable heat sources are used, or with limited access to solar radiation. These are discussed in the next section.

Buildings linked to district heating

Circa 12% of the total heat demand in Europe is covered by district heating, with high shares in some Eastern and Northern European countries. District heating offers a very high potential for integration of renewables, not only biomass and geothermal but also solar thermal. The largest solar thermal heating system in the world (13,8 MW_{th} capacity) is connected to a district heating network on an island in Denmark.
In buildings linked to a district heating network, a solar or renewable heat obligation on the single building would not be reasonable. In this case, the best way to increase the share of renewables is to invest in the district heating network itself. Specific financial incentives should be provided to district heating operators. An obligation should be considered, taking into account the specific potential and conditions of each region.

4.4.2 Definition of the required solar contribution

Most existing obligations require covering at least 30% to 80% of the domestic hot water demand from renewable energies.

It must be noted that these values represent only a small part of the coverage provided by many state-of-the-art solar thermal systems. In Austria, one of the leading markets in Europe, circa one third of the systems installed during the last two years are Combi-Systems, typically covering nearly 100% of the domestic hot water and 10-30% of the space heating consumption, and thus saving more than three times the energy produced by an obliged system defined as above. A large proportion of European buildings is suitable for the installation of solar Combi-Systems.

Of course, an obligation has to be defined moderately, in order to be reasonably applicable to all buildings. For the time being, ESTIF does not recommend requiring space heating in solar obligations, because at the current level of technological development, there is still a relevant share of buildings where space heating cannot be supported with solar at reasonable prices. However, in most European countries, the minimum share of domestic hot water should be at least 40%, as this is easily reachable almost everywhere by small solar systems. In the most Southern parts of Europe, obliged shares of 70-80% are feasible.
A gradation based on the estimated hot water demand for different building uses and sizes, and on latitude, as in the Spanish CTE, is reasonable (see annex).

If the obligation is set too high, it to excluding de facto solar energy. For instance, in a draft discussed in a Mediterranean city, a requirement of 50% of the total consumption for hot water and space heating was being discussed. Taking into account a space heating season of five months, and a limited available surface for

collectors in comparison with the typical building volumes, in most cases such a requirement would have been reachable only with biomass systems that automatically cover 100% of the demand.
However, given the uncertainty about the availability of sustainable biomass supply in the case of expected growth in demand, biomass use should not be obliged as the only possible option. Of course, solar thermal can also be perfectly combined also with biomass heating systems, reducing accordingly their consumption and emissions.

Renewable Heat Obligations that refer to the total demand for domestic hot water and space heating typically require 10% for existing buildings and 15-20% for new buildings. The first requirement can be fulfilled with solar domestic hot water systems, the latter with Solar Combisystems.

4.4.3 Solar or renewable heat obligations

Though mainly known as "solar obligations", several of those implemented so far are in fact renewable heat obligations, exempting from the solar obligation buildings covering this demand with other forms of renewables.

This approach reflects a political aim to increase the share of renewable energies and to leave to the market the choice of the technology most suitable for each building owner. While this aim is absolutely reasonable, it is useful to mention some comparative benefits of solar thermal that are often not reflected in the market prices faced by the investors.

Solar thermal systems provide completely clean and renewable energy, always resulting in net energy savings, regardless whether they are combined with an auxiliary gas, oil, biomass, electricity or heat pump system. The operation of the solar loop in natural flow systems does not require any electricity consumption and in forced circulation systems the consumption for pump and monitoring devices is negligible compared with the gains.
Therefore, the use of solar systems is always desirable, both from the perspective of the single user and of society.

Most **geothermal heating systems** use heat pumps, producing useful heat taken from a natural source (underground water, sea/lake/river water, air). They need a substantial electrical input. In real life, most heat pumps have a COP (Coefficient of Performance) ranging between 2,5 and 4. This means that they produce 2,5 to 4 units of heat by using one unit of electricity.
Thus, when replacing a conventional electrical heating, heat pumps provide a net benefit. If combined with solar, their benefit is even higher as a part of the electricity consumption, particularly in summer, is covered by solar.

However, when substituting a (more frequent) gas heating system, a heat pump system saves 100% of the gas consumption, but it massively increases the electricity

consumption. Considering the average efficiency of European power plants, the gain in term of primary energy may even be negative. Moreover, a wide use of heat pumps would lead to increases in winter peak electricity demand, causing hidden costs in terms of the necessary enlargement of electricity generation and transmission capacities.
Equipping the same gas heating system with a typical solar thermal Combi-System, gas consumption is reduced by 10-30%, with a very marginal (<1% of the gains) increase of electricity consumption.

In conclusion, the use of heat pump systems is always desirable when they replace electrical heating systems. When they replace gas, biomass or mainly solar systems, their benefits should be weighed with the public costs and risks linked to the massive increase of electricity consumption they imply.
The electricity consumed by heat pumps and the primary energy needed to produce that electricity should be subtracted from the heat produced by the pump, and only the remaining fraction should be considered as renewable.

In the case of **biomass heating systems**, it should be considered that the production and delivery of the fuel is linked with a more or less strong consumption of energy and other natural resources.
While in nearly all cases the CO_2 balance of biomass is clearly better than fossil fuels, some biomass heating systems cause high rates of locally polluting emissions. Furthermore, the use of biomass is also being politically supported for electricity generation and transport, and for the latter biomass represents the only form of renewable energy available today at a significant scale.
If the use of biomass would increase in all energy sectors (electricity, transport, heating) as projected by some analysts, it is doubtful if the availability and sustainability of bioheat fuels will be ensured. A coherent certification scheme for the sustainability of biomass still has to be developed. The biomass consumption and its environmental impact can be reduced in combination with solar thermal.

Therefore, the increased use of bioheat systems is desirable as long as the security and sustainability of biomass supply are reasonably guaranteed and the local emissions are limited. Biomass heating systems should be installed in combination with solar as often as possible.

Summing up: heat pumps and bioheat systems produce renewable energy, but have considerably higher external costs than solar thermal. The increase of winter peak electricity consumption caused by heat pump systems (except when they substitute for electrical heaters) should be taken into consideration. Biomass heat should be promoted, as long as the sustainability and availability of biomass heat fuels is guaranteed.
Therefore: renewable heat obligations should in any case be designed in a way that they support the use of solar thermal. In Southern Europe, there is a case for purely solar obligations, if the available biomass sources are scarce and the capacity of the electrical grid is not sufficient to support the increased demand from heat pumps.

4.4.4 Calculation of the fulfilment

Once the required share of solar or renewable heat is established, procedures for its calculation and possible verification must be defined.
Two pieces data are required: the hot water (and if relevant space heating) consumption and the production from the solar system. For both, it is necessary to define standard criteria, because the first verification of the fulfilment of the obligation is at the planning stage, when measurements are not yet possible.
For the hot water consumption, the Madrid regulation and the national Spanish CTE offer an example of a detailed definition taking into account the use of the building and its size. A similar approach is recommendable, though the data may have to be adapted to the local situation.
For the solar system performance, the calculation methodology should be based on the European standard EN15316-4-3 of 2007: "Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Heat generation systems, thermal solar systems."

4.4.5 Controlling procedures

The effective implementation of the requirements can and should be controlled by the public authorities at three points in time:

1. On paper, at an early stage of the planning of the building (or of the renovation): comparing the proposed installation with the legal requirements.
2. Before the building is commissioned, comparing what has been effectively installed with the legal requirement
3. After one or two years of operation, inspecting a sample of systems to see if they perform according to the requirements

The first and second steps are foreseen with more or less clear provisions by all solar obligations. In Barcelona, for instance, the revised Ordinance of 2006 includes a model declaration to be signed by the installation company after the works are completed. This declaration includes the data needed for the public authority to determine if the installed solar system complies with the requirements.

However, it is not always clear if and how often on-the-spot checks are undertaken. Like for any other building regulations, the rate of compliance will be higher if there is a significant likelihood of an inspection. For solar systems, underperformance is most frequently caused by installation mistakes. Thus, the standard document-based controls should be accompanied by sufficiently frequent inspections on the spot. These should be performed by specifically trained and motivated staff. If appropriate, this service can be performed by external companies, whereas care must be taken to avoid a conflict of interest between the inspectors and the installing companies.

Particularly during the first period of implementation, low compliance is more likely due to the scarce knowledge and/or willingness within the construction companies.

Therefore, relatively frequent inspections should be announced from the first day of implementation of a solar obligation.

To our knowledge, no solar obligations foresee the third kind of inspection[2]. Presumably with the intention of achieving the same effect, the Spanish CTE prescribes instead a number of technical details about the components and the configuration of the system. As discussed below (see annex), such a prescriptive approach has several disadvantages.
Instead, it is recommendable to announce random inspections on a sample of the systems installed under the obligation. On the basis of the required function control devices, skilled staff should check the functionality of the systems, for instance after one year of operation. In case of significant underperformance, the installing company should be obliged to repair or improve the system at their own cost.
The information gathered through these inspections should be made available, at least in anonymous form, to research institutes and industry, that can use it to improve products, system design and installation procedures.
A "name and shame" policy could be considered, giving the installers and manufacturing companies a strong incentive to guarantee high quality products and services.

This third kind of inspection should be applied more frequently to large systems, but also a few small systems should be inspected to make sure that quality issues are not neglected in this area.

The energy agency or the public body with the task of monitoring the implementation of the solar obligation should have the right to access the systems and to adjust the inspection procedures and frequency according to the needs. Presumably, after a couple of years of experience, the increased level of knowledge of the involved companies and staff, as well as the increased awareness of the users and citizens, will allow for a reduced level of inspections.

4.4.6 Sanctioning regime

In a strongly competitive and price-driven market like the building sector, regulations are implemented only if the sanctions are clear, predictable, strong and frequent enough.
In this case, construction companies integrate the check of compliance into their standard quality management procedures. If the sanctioning regime is too weak, no or low compliance may be a rational strategy for construction companies.

[2] A kind of exception is a quasi-obligation in the Austrian region of Styria, where the use of renewable heat is a condition for receiving the strong public financial support foreseen for those building their own new residential building. Because (almost) nobody wants to miss this subsidy, (almost) everybody fulfils the requirement. However, this is not an obligation in the strict sense, and was therefore not considered in the present study.

This is particularly true for solar regulations in their first period of implementation, as construction companies are not yet used to dealing with solar energy:

- the costs of learning how to integrate a new element in the construction process are higher
- the low level of training makes mistakes more likely
- the final users of the solar system, i.e. those who will live or work in the building, are less able to perceive possible underperformance of the systems
- the companies might be tempted to "test the public authority" and see what happen if this additional legal requirement is not met

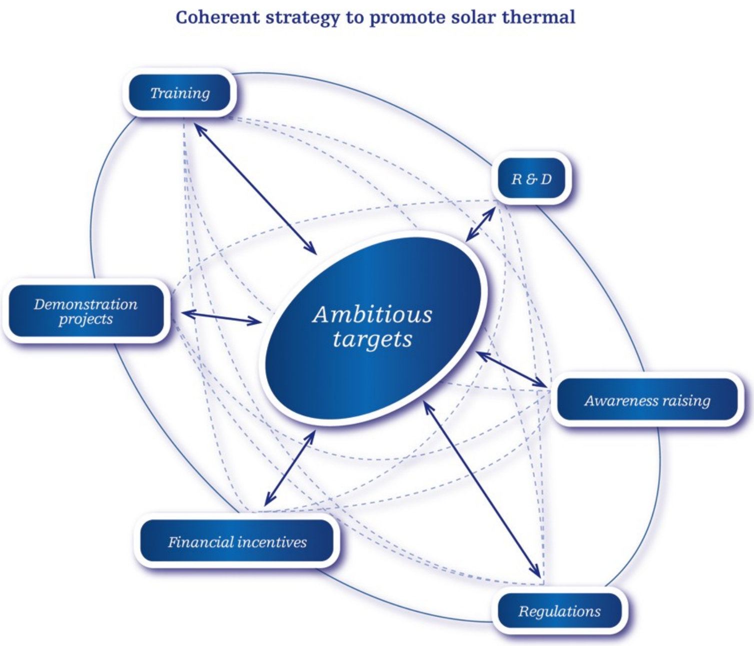
In the field of solar regulations, the case of Vellmar (see annex) is an example of a credible sanctioning regime, but the sanction was too low. In Spain, there are great worries about the effectiveness of the sanctioning regime of the CTE, especially as the monitoring and sanctioning is responsibility of the regional administrations which may have other priorities, while the legislation was adopted at the national level.

A convincing sanctioning regime is strictly necessary for a successful solar obligation. Without it, there is a significant risk of a high rate of low quality systems, possibly leading to a reduced acceptance of the obligation or even of solar energy as such.

The sanctions should be applied after all control phases discussed in the previous section. The installing company should be made responsible for solving, at its own cost, major failures or underperformance, of course without prejudice to the warranty and liabilities of the manufacturers. However, both the users and the public authority should have only one contact person responsible for the whole solar system.

4.5 Flanking measures for solar obligations

The main message of the *Solar Thermal Action Plan for Europe*, produced by ESTIF within the K4RES-H project, is that a coherent set of different, long-term oriented measures are necessary to achieve ambitious targets.



Solar obligations should not be seen as an isolated measure, but rather as a part of a wider plan to promote the use of solar thermal. For instance, R&D efforts are necessary to develop tomorrow's solar energy solutions.

In light of the analysis above, to be successful solar regulations need some flanking measures, mainly for two purposes:

- maximising their effect in the obliged sector
- promoting the use of solar in the voluntary market, i.e. for the buildings or uses not subject to the obligation.

As seen above, solar obligations only cover a small part of buildings and prescribe only a minimal level of solar energy use that can be economically implemented in all new buildings. This means a large part of the potential use of solar thermal cannot be obliged: the use of solar in existing buildings not undergoing a major renovation, and the use of solar beyond the strict legal requirements, for instance for space heating or cooling, in industrial processes, in the agricultural sector, for desalination etc.

If all the usual support schemes like financial incentives, awareness raising, and demonstration projects would be stopped when a solar obligation is adopted, the potential users might see this as an implicit message of the public authority that the use of solar beyond the obligation is not desirable. This impression must be avoided.

Therefore, support schemes focused on the voluntary market should continue. In case of buildings subject to the obligation, of course, the incentive should be given only for the solar capacity above the limit prescribed by the obligation.
Within the K4RES-H project, ESTIF has produced an extensive study with detailed guidelines on best practice financial incentives. For details, please see: www.estif.org/stap

Furthermore, intensive and focused training and awareness raising campaigns are highly recommendable during the first phase of implementation of a solar obligation.

A number of managers of construction companies, architects, heating engineers and installers who never dealt with solar energy before are suddenly forced to use it. If sufficiently trained, they will do so at a state-of-the-art level, and they will become motivated to go solar beyond the legal requirement. If not, there is a higher risk of low compliance or quality problems. Setting up training courses is therefore recommended, as well as a certification scheme to demonstrate the solar qualification of the key professional figures involved.

ANNEXES

Annex 1: 27 years of solar obligation in Israel

Back in 1980, Israel was the first country to make solar thermal obligatory in new residential buildings, with the aim of reducing the country's dependence on imported energy. According to governmental sources, today Israel saves circa 8% of its electricity consumption thanks to solar heating systems.

The obligation applies to all new buildings, except those used for industrial or trade purposes or as a hospital, and those higher than 27 metres. The required daily heat output of the solar system differs according to the use of the building and on the kind of solar system installed.
For ordinary residential buildings, the obligation is defined in terms of daily solar energy output per litre of storage tank capacity: 172 kilojoules for open loop systems, and 192 kilojoules for closed loop systems.
The required tank capacity is determined according to the number of rooms in each residential unit: at least 60 litres for one room apartments, at least 120 litres for two or three room apartments, at least 150 litres for larger ones.

For hotels, guest houses, elderly homes, boarding schools and similar, the obligation is defined in terms of daily solar output per litre of hot water consumption: 126 kilojoules for open and 142 for closed loop systems.

The obligation became a success and made solar thermal a mainstream technology in the water heater market without any financial support. In Israel, solar thermal has reached the critical mass of market size necessary to create self-sustained growth without any subsidy. Systems are available for purchase everywhere, installers know how to set them up, prices have decreased substantially: a small open loop system, including installing costs less than 500 EUR.

With almost 600 kW_{th} solar thermal capacity installed per 1000 inhabitants, Israel is the second country in the world for solar thermal use. By reaching the same level, the European Union would save circa 18 million tons oil equivalent yearly, enough to cover the total hot water and space heating consumption of ten million households.

The law's success has made it largely superfluous. Today, more than 90% of Israel's solar thermal market are in the voluntary segment, like installation on existing buildings, or systems bigger than required by law. Typical payback times are around three of four years. People consider solar thermal systems an obvious component of buildings.

Annex 2: Solar obligations in Spain

This summary is based on following documents produced within the K4RES-H project available, all of them available at: www.estif.org/stap > regulations.

- An extensive study about the implementation and revision of the Barcelona obligation, produced by the Barcelona Energy agency. The 50 page version is available in Spanish and Catalan, the summary flyer also in English.
- An extensive study comparing the development and the contents of more than 60 municipal obligations, more details about the obligation in the City of Madrid, and a summary of the new national Technical Building Code, This was produced by IDAE (Institute for Energy Diversification and Saving), the Spanish national energy agency. Full version and the summary flyer are available both in English and in Spanish.
- A complete English translation of the legal text relevant for solar thermal within the national Technical Building Code of 2006.

It takes several years before solar obligations have a direct impact in terms of installed solar systems. Usually, there is a gap of several months or even one year between adoption and entering in force. The obligation refers to the permission for building. From the permission to the installation of the system, it can take further two years in average, and some more time before the building is inaugurated and the systems start to work.

The solar obligation in Barcelona and its upgrade

The first solar obligation ("Ordinance") was approved by the City Council in 1999, and entered into force in August 2000. After some years of experience, the Ordinance was modified, and the new version entered in force in 2006.

The Ordinance and its revision were approved after an extensive consultation process, including the professional associations of the affected sectors, including constructors, building administrators, architects, engineers, installers, consumers and tenants, solar and renewable energies and others, as well as the local, regional and national energy agency and the public bodies responsible for housing, urban planning, protection of architectonic heritage and environment.

Description of the current Barcelona Ordinance

The current version of the Ordinance is applied to new buildings, those undergoing a complete refurbishment or changing their function, i.e. when an authorisation for construction is required. The Ordinance applies to residential buildings, sport centres, hospitals and other health care facilities, industrial buildings using hot water for their process or for showers, some tertiary buildings, and any other use implying the presence of refectories or common laundries.

The minimum solar output is defined as a share of the energy needed to produce hot water. It depends on the estimated daily demand for hot water in the building, and on the kind of back up energy used:

Daily hot water demand (in litres at a reference temperature of 60°C)	Minimum solar fraction (backup non electrical)	Minimum solar fraction (electrical backup)
< 1.000	60	60
1.000-2.000		63
2.000-3.000		66
3.000-4.000		69
>4.000		70
10.000–12.500	65	-
>12.500	70	-

For indoor swimming pools, at least 30% of the energy consumption shall be covered by solar thermal energy. For outdoor swimming pools, no other heating systems than solar are allowed. For industrial uses up to 60°C, the solar fraction shall be at least 20%.

The Ordinance provides a clear list of conditions allowing for exceptions. A complete exemption from the obligation is allowed in the following cases:

- In the buildings where it is not possible to cover more than 25% of the hot water demand by solar heating; however, in the non residential sector this exemption is valid only if the total daily demand that can be covered by solar is not higher than 90 MJ.
- The non residential buildings with a daily hot water demand lower than 20MJ.

Under the following conditions, it is allowed to reduce the required solar fraction:

- If the building has not sufficient access to the sun due to external barriers
- In case of refurbished buildings, if the previous configuration creates serious architectonical barriers
- If the surface available to install solar collectors is not sufficient
- Where the hot water demand is covered by other renewable energies, cogeneration, waste or free heat: in this case the solar system will be designed to cover only the remaining demand for hot water, if any.

It is important to note that the latter exemption means that, in reality, the Barcelona Ordinance is a renewable heat rather than a solar obligation. The fact that solar is by far the most used option is due to its attractiveness in the context of Barcelona. However, there is no technology bias, as the obligation can be fulfilled also with other forms of renewable energy.

Results of the implementation

Before the adoption of the first ordinance, the use of solar thermal in Barcelona was negligible: with only 1650 m^2, Barcelona had 0,77 kW_{th} / 1000 inhabitants of solar thermal capacity in operation, circa twenty times less than the average of the European Union in that time.

In less than five years, Barcelona multiplied by twenty times its solar thermal use per capita. After the first Ordinance entered into force, 21,7 MW_{th} (31.050 m^2) solar thermal capacity have been added in Barcelona, producing 24.480 MWh of solar energy per year , equivalent the hot water demand of circa 45.000 inhabitants. The solar thermal systems allow for savings of 4.368 ton CO_2. Because the obligation applies to the moment when the building permission is given, there is a natural delay of two to three years until the solar systems are in operation.

63% of the new solar thermal capacity was installed in residential buildings, 20% in hotels, 8% in sport centres, 3% in health care facilities. Roughly 15% of the buildings in principle subject to the regulation were exempted, the main reason being lack of space for the collectors or shadowing from neighbouring buildings.

It must be noted that these data refer to the authorisations awarded until the end of 2005.By that time, only 20% of these systems were already operational, reflecting the physiological delay mentioned above, but also the slow start in the implementation of the Ordinance. By now (June 2007), most of the systems counted above should be operational.

The qualitative change in the perception and handling of solar thermal energy in Barcelona, its surroundings and beyond has probably been even more important than the mere quantitative results in terms of system installed under the obligation.

A large number of installers, architects and building engineers got trained and gained practical experience with solar thermal technology. The constructions companies became used to include solar from the earliest stage of planning, thus reducing the time and costs needed to integrate it at a later point. Citizens and potential users were informed about solar. Though no detailed figures are available, several solar thermal companies believe that the solar obligation led to a sensible increase of installations also in the voluntary market of existing buildings in Barcelona and its surroundings.

Beyond these local effects, the "Barcelona model" was followed by a number of municipalities in Spain and abroad, and is meanwhile being discussed also at national level in several European countries. This debate is encouraging the solar thermal industry to significantly invest in production facilities, distribution networks and marketing, leading to increased production capacities and economies of scale.

Lessons from the Barcelona experience

The experience gained in the implementation of the pioneer solar obligation in Barcelona, and the changes undertaken in its revision, are interesting for the solar industry and for all public authorities considering to implement a similar measure.

> *"Since its first adoption, we experienced a qualitative conceptual change, as the solar thermal installation is not anymore perceived as an «obligation», but rather as a «guaranteed right»: a norm that guarantees the right to be supplied with solar energy."*
> (Barcelona Energy Agency, K4RES-H study quoted above).

However, initially, the practical implementation of the obligation was made difficult by the lack of training and practice of installers, architects, building engineers and decision makers in the construction industry. The solar systems were often planned at a later stage increasing costs and sometimes the visual impact, in certain cases the lack of familiarity with the technology caused the use of wrong materials or calculation methods.

This resulted in a higher rate of exemptions during the first period. Some of the solar systems installed did not fulfil the requirements of the obligation. In other cases the wording of the regulation was fulfilled, but the solar systems produced less output than expected due to weak installation works, design or maintenance.

A survey of the users of the solar systems showed a high degree of satisfaction in cases of centralized systems serving a whole building, and a medium level of satisfaction in the case of decentralised systems, serving a single flat each (detached houses are very rare in Barcelona). A survey of the technical state of the installations revealed that the majority is working properly, but there is a significant share of systems with occasional faults, mainly linked to lack of maintenance, overheating, or leaks in the collector loop.

Comparing the 1st and the 2nd version of the Barcelona Ordinance

The main lessons learned by the administration in Barcelona have materialised in the revision of the Ordinance, that started in 2004 and was adopted in 2006.

The main changes reflect the general positive experience with the solar obligation: the number of buildings subject to the obligation increased, as well as the required solar fraction.

At the same time, the revision corrected some of the weaknesses identified during the first period of implementation. In particular, the quality of the installation works has to be certified and a maintenance contract must be provided, thus increasing the quality assurance measures as suggested by the experience mentioned above.

Ordinance of 1999	Ordinance of 2006
Obligation was applied only to buildings consuming more than 2000 litres hot water a day (i.e. larger than circa 14 residential units)	No minimal consumption threshold for a building to be subject to the obligation
Minimal solar fraction for heated swimming pools > 100 m^3 was 30%	Minimal solar fraction for heated swimming pools > 100 m^3 is 60%
Minimum solar fractions varied according to the hot water demand	In all buildings, the minimum solar fraction is at least 60%
No such requirements	A certification of the quality of the installation work and a maintenance contract are required
Higher presence of technical details in the legal text itself	Simplification of the legal text, more technical detail are relegated to annex, therefore easier to be modified

The solar obligation in Madrid

The Madrid solar obligation was officially adopted in May 2003, after one year of consultations and preparation. It entered into force in November 2003.

IDAE played an active role as consultant for the Municipality of Madrid and at the same time, IDAE was also supporting the national government, while preparing the solar chapters of the National Building Code. Therefore, the Madrid regulation is coherent with the latter, discussed below.

Due to the physiological delay mentioned above, the only data available until now are related to the permission of construction, and not yet to installed systems. In the first 26 months of applications, the awarded permissions for constructions included 19,7 MW_{th} (28.197 m^2) new solar thermal capacity, which represents a dramatic increase. Given the structure of the new buildings in Madrid, 23% of the permits refer to large (>100 m^2) solar systems, often in the tertiary sector (shopping centre, office buildings). 45% of the permits refer to systems small (<20 m^2).

Like in Barcelona, also in Madrid the industry is experiencing a significant growth in the voluntary sector as well, i.e. in buildings not subject to the solar obligation. The training, awareness raising and the increased marketing efforts stimulated by the obligation are creating an additional benefit.

Compared with the first Barcelona Ordinance, the Madrid obligation introduced some important changes which have been integrated into the revision of the Barcelona ordinance and, therefore, have been mentioned above. Among them: the required solar contribution is based on the building's consumption, a solar contribution is required also for buildings with small consumption, the design temperature of the solar system is defined at 60°C (instead of 45 °C as in the first Barcelona Ordinance), and the technical requirements are described in annex and not in the legal text itself.

In order to determine the required solar thermal capacity, the regulation defines standard values of hot water consumption, that vary according to the kind of buildings. The same approach has then been used in the National Building Code.

Type of Demand	**Litres of DHWD/day at 60º C**	
Single-family dwellings	30	per person
Multi-family dwellings	22	per person
Hospitals and clinics	55	per bed
Hotel ****	70	per bed
Hotel ***	55	per bed
Hotel/Hostel **	40	per bed
Camping	40	per site
Hostel/Boarding house *	35	per bed
Homes for the elderly, student dormitories, etc.	55	per bed
Dressing rooms/collective showers	15	per service
Schools	3	per pupil
Barracks	20	per person
Factories and shops	15	per person
Administrative premises	3	per person
Gyms	20 to 25	per user
Laundromats	3 to 5	per kilo of clothing
Restaurants	5 to 10	per meal
Cafeterias	1	per meal

Besides this, in Madrid it is compulsory to install a measurement and control system which provides information on the basic parameters of the system and its production.

Also taking into account the experience in Barcelona, Madrid paid close attention to the training of the council staff, to ensure a proper implementation of the obligation. At the same time, extensive consultations was carried out with installers, engineers, architects, construction industry and with the solar thermal sector. The result of this consultation reported in the study give an interesting insight.

The national Spanish solar obligation (CTE)

With the approval of the Technical Buildings Code (CTE, Codigo Tecnico de la Edificacion) in 2006, Spain became one of the countries with the most advanced solar legislation in the world. The municipal solar obligations remain in force as long as they have stronger requirements than the CTE.

The CTE has been the most significant reform of the Spanish building sector for decades, covering security of the buildings structure, fire safety, other safety and health issues, sustainability and energy efficiency of the buildings. The latter part goes far beyond the minimal level of implementation of the EC Directive on the Energy Performance of Buildings and includes an obligation to cover 30-70% of the Domestic Hot Water (DHW) demand with solar thermal energy.

The first buildings subject to the CTE have been authorised in late 2006 and will therefore not be finished before 2008. No post-hoc data on its implementation are therefore available.

Based on different scenarios on the development of the construction market, the Spanish government expects between 1050 and 1750 MW_{th} new solar capacity to become operative until 2010, leading to yearly savings between up to 165.000 of tons oil equivalent.

Main clauses of the CTE

The solar thermal part of the CTE applies to any kind of new buildings, independent of their use, and to those undergoing a renovation. Exceptions are foreseen in the case of buildings that satisfy their DHW demand by other renewables or by cogeneration, meaning that also in this case the "solar obligation" is in reality a renewable heat obligation. Other exceptions are buildings with insufficient access to the sun, or under specific historic-artistic protection. In these cases, the reduced or absent solar contribution must be compensated by other measures leading to the same result, like energy efficiency or other renewables.

The required solar fraction of the domestic hot water demand varies from 30-70%, depending on following parameters:

1) The assumed volume of DHW demand: the larger the consumption, the higher the required solar fraction. This is due to the fact that solar systems are more effective if the heat load (i.e. the consumption) is higher. The CTE defines typical consumption as the Madrid regulation (see table above):

2) The kind of back-up energy: in case of electricity, the required solar fraction is higher than in case of gas or oil back up.

3) The level of solar radiation available. The CTE divides Spain in five climatic zones and allocates each province, or in some cases smaller territorial units, to one of these zones.

Having determined the required solar contribution, the CTE contains prescriptions on the method to calculate the system performance and on the required maintenance procedures.
The CTE defines a number of technical requirements on the components, design and installation of the solar thermal system, including sections on the solar collector and its components, the working fluid, the storage systems, the hydraulic circuit, the controllers and the conventional auxiliary system.
These technical requirements cover dozens of pages and can not be discussed in detail here. This high level of detail originates from the wish of the government to assure the quality and the proper working of the solar systems and to reduce the possibility of different interpretations, thus creating more legal clarity. The CTE also contains detailed prescriptions on the regular inspection and maintenance operations to be carried out by trained personnel.

Discussion on the prescriptive approach

Looking at the CTE, several experts from the solar thermal sector expressed doubts whether this approach based on detailed prescriptions is suitable. It is argued that a result-oriented approach would be more desirable: instead of prescribing a number of technical solutions, it might be more useful to foresee checks on the effective performance of the solar thermal systems and foresee sanctions, like an obligation to improve them, if the a significant under-performance is ascertained.

Some of the general arguments against the risk of over-prescriptive regulations are :

- The transaction costs implied by the need of justifying special solutions may discourage solar companies from trying to find optimal tailored solutions and lead to the use of sub-optimal solutions explicitly approved by the CTE.
- Some solutions may be valid in general, but sub-optimal or even not applicable in specific situations.
- The prescriptions risk to be discriminatory against certain kind of solar components, technologies or designs, particularly in the case of niche-solutions that easily tend to be neglected while defining general rules
- Development of new technologies or system design may be hampered
- The prescriptive approach may deflect attention from the effective purpose of the quality assurance measures: to guarantee that the solar systems installed produce the expected amount of energy for a long time.

Unclear sanctioning regime

However, these prescriptions do not include clear rules about the monitoring of their implementations by public bodies and about the sanctions to be applied if the system is not delivering the expected energy.

The responsibility to monitor the implementation of the CTE and sanction the non compliant constructors is delegated to the regional authorities, which might not have the human resources and/or the political will to follow up closely this matter. Currently, there is not yet any experience with this stage of the implementation of the CTE, since the first buildings subject to the CTE have been authorised in October 2006 and have therefore not yet been finished. However, the Spanish solar thermal industry believes that this could become a serious limit to the application of the CTE.

Annex 3: The debate on solar obligations in Germany

As mentioned above (Chapter 4.1.), the first place in Europe where a solar obligation was seriously discussed was Berlin in the mid 1990s. Though the Berlin obligation was not approved in the end, the solar thermal market in Germany was boosted by other means: strong awareness raising campaigns, R&D funds and above all the *Marktanreizprogramm* (MAP), a financial incentive scheme that has been running since 1999. For several years, Germany alone has made up half of the solar thermal market in Europe, and benefits from around 40% of the total solar capacity in operation.

On the whole, compared with financial incentive schemes operated in most other countries, the MAP has been a remarkably long-term and relatively stable support scheme. However, the market development in Germany has been characterized by some significant ups and downs, with notable deeps in 2002 and in first half of 2007 (last update: August 2007). Most analysts believe that an important factor in this market instability, at least in 2002, was the frequent uncertainty of the MAP: its dependence on the federal budget makes it vulnerable to political instability.

For details on how to design stable financial incentive schemes, please see the related study produced by ESTIF within the K4RES-H project at www.estif.org/stap

The damage caused by this instability has brought the discussion of a possible solar or renewable heat obligation back to the agenda. The implementation of a "Renewable heating law" is part of the coalition agreement of the current CDU/CSU-SPD government, though at the beginning it was not clear what this law would contain. In June 2007, the conservative (CDU-FDP) government of the Federal State of Baden-Württemberg proposed a law for a renewable heat obligation to be applied in Baden-Württemberg. Consultations are currently ongoing (last update: August 2007). At the federal level, no law has been proposed yet but it seems that the discussion is moving towards a renewable heat obligation accompanied by a continuation of other support schemes like financial incentives, training and awareness raising campaigns.

Beyond the instability of the financial incentive schemes, this political development is sustained by other factors, like the growing urgency of the security of energy supply and climate mitigation policies, as well as by the trend towards solar obligations in other countries.

Moreover, the positive experience with a sort of solar obligation in the town of Vellmar in central Germany has contributed to creating a first experience and model for discussions in this country.

The solar obligation in Vellmar (Germany)

The municipality of Vellmar, with approximately 20.000 inhabitants, set the installation of solar thermal systems as a preliminary condition for the authorisation to construct in the new development area of Osterberg.

Osterberg was a major and, for the foreseeable future, the last residential development area to be authorized in Vellmar. It covers an area of 12 hectares. When fully developed, it will have 200 residential buildings with 350 residential units. Given the size of the town it is a major development, as it could host in the future roughly 5% of the population of Vellmar.

After years of debate, the plan was publicly discussed during the local election campaign in 2001. While the SPD confirmed its absolute majority in the city council, those candidates proposing the solar obligation won a particularly high consensus; this was interpreted as support from the voters for the Osterberg solar plan.

It was the first time in Germany that such a legal scheme was adopted. The clarification of its legal feasibility absorbed a substantial amount of energy of the small city council and caused some delay. The regulation was supported by a very large majority in the city council.

At the same time as constructions in the Osterberg areas were authorized in principle, the city council included in the contract to be signed by the building developers the use of solar thermal energy and other environmental measures as a binding condition. However, as a political compromise, it was possible to be exempted by paying a relatively low fine. This explicit buy-out option was very controversial.

The obligation was only a part of the energy policy of the municipality, under the motto "Fördern und fordern" (promote and require). Other elements were a free energy consultation and a grant for building owners who also installed a rainwater harvesting system.

By summer 2005, the first section of construction was concluded, including 94 buildings with 100 residential units. 73 of these buildings had installed a solar thermal system, with a total capacity of 273 kW_{th} (390 m^2). The second construction section consisted of larger buildings with several residential units each. In summer 2005 it was being realised, with a provisional balance of 7 out of 9 buildings due to install a solar system.

In sum, around 80% of the buildings constructed by summer 2005 had a solar system installed, while a significant minority of 20% opted to pay the fine. It is interesting to note the huge difference in the compliance rate between commercial building developers and households building their own home. Nearly 100% of the latter chose to install the solar system, while slightly over 50% of the former opted to pay the fine.

An extensive scientific survey of the inhabitants and building owners of Osterberg was performed by the Institute of Psychology of the University of Kassel at the end of 2005, supported by the K4RES-H project.

All building owners and inhabitants of Osterberg were approached, and more than 50% participated in the survey, including face-to-face interviews and a questionnaire.

The survey shows a very high acceptance of the solar obligation from those subject to it. The prevailing reasons for choosing to build in that area were not the solar obligation itself, but a broad majority found its existence to be a positive aspect.

Slightly more than 10% of those who installed a solar system voluntarily opted for a Solar Combisystem covering also space heating and thus going far beyond the minimal requirement of the obligation. An overwhelming majority would choose again to install the solar system and would recommend it to a good friend.

This summary is based on a case study and the survey of the inhabitants realised under the coordination of Energie2000, the Energy Agency of the region of Kassel, as a part of the K4RES-H project coordinated by ESTIF.

The following materials (in German only) are available at http://www.estif.org/262.0.html :

- Short flyer
- In-depth report and analysis with legal background
- Report on a survey conducted on the citizens involved
- PowerPoint presentation

Annex 4: Solar obligations in Italy

National level

A renewable heat obligation is included in the law implementing the European Directive on the energy performance of buildings. The following information refers to the legislative decree 311 of 29 December 2006, that has amended a previous version.

Concerning the renewable heat obligation, the decree prescribes that at least 50% of the annual domestic hot water demand must be covered by renewable energy sources, whereas in the city centres with historical value the share is reduced to 20%.

The renewable heat obligation will be applied to all buildings, and not only those in public ownership as in the previous version. The obligation will apply to new buildings, major renovations and in case of replacement of the heating system.

The provisions about the renewable heat obligation are not yet applicable, because the implementing decrees ("decreti attuativi") have not yet been adopted.
For the national renewable heat obligation to have a real effect, it is necessary that the implementing decrees are adopted and that they contain clear provisions effectively ensuring a high rate of compliance. Otherwise, there is the danger to replicate the experience of the law 10 of 1991, that was very demanding on paper but to a large extent was not observed in practice.

Local and regional level

Some initiatives at the local level have been developed in recent years. Here the positive example of a number of small communes in the Province of Milan are analysed, as well as a law from the Regione Lazio that is an example of the frequent "nice" laws that are not applied due to a lack of sanctions and realistic enforcement procedures.

Carugate and other communes around Milano

In 2003, the municipality of Carugate, close to Milano, population 15.000, adopted a new building regulation with strong attention paid to the reduction of energy consumption. In particular, it included an obligation to meet at least 50% of domestic hot water demand from solar thermal energy. Other measures like photovoltaic or radiant floor heating are facultative.

The main actors involved in the regulation development and management are:

- The Carugate Municipality, which volunteered to promote this "pioneer" experience for mandatory solar thermal in Italy;
- The "Rete Punti Energia", a network of energy agencies in the Regione Lombardia, which gave the Municipality the necessary technical support;
- Professionals within the building sector (designers, construction companies, etc.), who have been involved in the regulation development from the beginning;
- The Province of Milano, which has worked to extend this kind of building regulation to other Municipalities.

Factors that contributed to the approval of this regulation were the discussion about the European Directive on the Energy Efficiency in Buildings, the model of the Barcelona "Solar Ordinance" and the growing general interest of local authorities for the promotion of sustainable buildings.

The regulation has been in force since the end of December 2003. It covers new buildings for several final uses: residential, commercial, industrial, tertiary, and collective use buildings (cinemas, theatres, hospitals, sport halls, schools, etc.).
The main technical requirements are:

- At least 50% of the DHW demand is covered by solar thermal (100% in the summer months);
- The collectors can be oriented south, south-east or south-west;
- On tilted roofs, the collectors shall be installed with the same inclination and azimuth as the roof;
- Water storage should be preferably installed inside the building;
- On flat roofs, the collectors shall not be seen from street level.

Regrettably, there is no quality requirement on the solar products.

As a technical aid, the Municipality made available a very simple Excel sheet, by which the collector surface needed to reach the 50% solar fraction could be calculated. However, there is no standardised system to determine the expected domestic hot water demand that can be set by the construction company.
Two checks are foreseen: the first one is when the project is evaluated and the designer should fill in a check list highlighting the main parameters of the solar thermal plant. The second check is during the works, when the solar panels are installed.

During the first two years of application, the regulation in Carugate resulted in around 220 kW_{th} of new solar thermal capacity already installed or approved as projects. In a very short time, per capita, Carugate reached a level of solar energy use nearly 30 times higher than the national average. Typically, the additional costs due to the solar obligation are around 0,5% of the total cost of the building, resulting in a substantial reduction of energy bills for the next twenty years at least.

A key positive aspect of the Carugate regulation was its pioneering character in Italy, and the proactive dissemination campaign started in March 2005 by the Province of Milano, in collaboration with the University "Politecnico di Milano" and with 13 Municipalities. They jointly developed common guidelines for sustainable building regulation. A growing number of municipalities have their "sustainable building regulation" approved and some more are on the way. While the largest cities of the area have not yet joined, circa 150,000 people in Regione Lombardia live in communes under such regulations by now.

Another positive aspect was the wide consultation carried out before adoption of the obligation, including all relevant actors such as building companies and final users. This contributed to a high acceptance and to the promotion of awareness and knowledge about energy efficiency and solar energy, also due to special initiatives in schools. Moreover, a local bank offered a 5-year low-interest loan for energy efficiency projects, called "Energy Mortgage". However, this was weakly communicated to the heating installers, and therefore also many final users did not know about this loan.

On the negative side, the complete lack of quality requirements for solar thermal products and installation could lead to quality problems and this could in its turn lead to a negative attitude towards the solar technology. Currently (last update: October 2006), no specific data in this sense are available. However, as discussed extensively in the main part of this document, quality assurance measures are absolutely necessary when adopting solar obligations.

Moreover, it must be taken into account that the rate of new build in Carugate and in many communes around Milano is not very high, and therefore the global impact of the initiative could be limited if measures are not taken to increase energy efficiency and the use of renewables in the existing building stock as well.

Regional law in Lazio

Regional Law no. 15, passed on 08/11/2004, has the aim of promoting solar energy and rational use of water in buildings. The scope includes new buildings and those under refurbishment, but all buildings located in historical areas are exempted.

The Regional Law does not define any detail of the specific measures to be applied, leaving to the Municipalities the duty to define the details for the practical implementation. This should be done by the Municipalities taking into account their landscape, historical constraints and environment.

The thin text of the regional law is available at:
www.ambientediritto.it/Legislazione/Energia/2004/lazio%20lr2004%20n.15.htm

The regulation concerns solar thermal systems for domestic hot water, rainwater collection and, more generally, the rational use of water. This report focuses only on the solar parts.

No implementation methods are defined in the text of the law, except for the fact that the Municipalities will be in charge of applying the law and also of checking the compliance of the building projects with established rules.

This makes the Lazio regulation very weak, especially taking into account that the Regional government did not take any action to support the Municipalities in their task or, at least, to make them aware of the requirements they have to comply with. It must be noted that the Region of Lazio has a population of around 5.120.000 and 378 communes. One of them is the city of Rome, with more than 2.500.000 inhabitants. Leaving aside some other major towns, one sees that the majority of the municipalities within Lazio have less than 5.000 inhabitants. Accordingly, their human resources are very limited and this makes it impossible for most of them to develop the technical details of such a regulation.

The Municipalities should have complied with the law within 180 days, i.e. by May 2005. As far the authors are aware, by summer 2006 no municipality had effectively enforced the regulation. The Commune of Rome has approved the legal basis for a solar obligation, but also in this case the technical specifications are missing and therefore the obligation cannot be applied.

The fact that the Municipalities so far have not complied with the regional law is due essentially to the concomitance of three reasons:

- No sanctions for non-compliant communes are foreseen in the regional law;
- The Region did not put any pressure on the Municipalities in order to have the law respected;
- There is a lack of knowledge on solar thermal on the side of the Municipalities and therefore no practical actions could be taken.

For the government of the Regione Lazio, the administrative and political costs of approving this regulation for the Regione have been remarkably low: all the work to define the technical parameters and to enforce the regulation is delegated to the communes. Taking into account the clear advantage of having the same technical parameters in all communes of the same region, it would have been reasonable to define them at regional level. Given the small size of most communes in Lazio, it can be easily foreseen that the regulation will never be applied in most of them, unless a further impulse come from other sources

From this point of view, now a first step in a new direction has been taken: the Municipality of Roma is working to publish a regulation obliging the use of solar thermal to meet at least 50% of the sanitary hot water demand for new buildings. This new initiative could act as a starting point to spread the introduction of solar thermal in building regulations to the whole Region.

There was hardly any consultation with the professional groups active in the solar energy and building sector.

No replication is advisable of such a generic regulation. Its real intention seemed to be to attract positive media attention, since solar energy is popular in Italy. However, with the lack of any sanctions, technical parameters and enforcement procedures, in the Italian institutional context such a regional obligation makes little sense.

However, such a regional solar obligation could be very useful if it would entail a complete set of detailed provisions, as widely discussed in the present document, thus empowering the communes to simply transpose the new solar element into their building regulations, taking the regional law as a technical and legal reference. Also, the enforcement procedures, including inspections, should be organised by competent institutions at the regional level, like energy agencies, thus reaching economies of scale. It cannot be expected, and it would not be reasonable, that each small commune train its own solar experts to follow-up a very small number of new buildings.

Annex 5: Solar Obligations in Ireland

Starting at the end of 2005, a number of Irish local authorities introduced building energy standards as part of planning requirements in their jurisdiction. These building energy standards require a substantial increase in the energy performance of new buildings (between 40% and 60% reduction in energy usage) as well as a mandatory contribution of renewable energy to their thermal energy requirement.

The Irish political system is generally very centralised and local authorities have limited power and resources compared to many other European countries. Within the 'geographical' scale of political influence, County Councils are the most influential organ of public authority at a local level. There are 26 counties in the Republic of Ireland.

Until recently, national government had exclusivity in terms of defining energy standards for buildings in the framework of the national Building Regulations. This position was challenged in October 2005 by Fingal County Council, as it introduced improved building energy standards in the Local Area Plan (LAP) for the Cappagh Road (a 29 hectare area of this county rezoned for housing).

The energy standard requirements that all new buildings must achieve as a prerequisite to receiving planning approval are:

- Annual heating requirement to be lower than 50 kWh/m^2 per year and;
- At least 30% of the building's space and water heating requirements to be supplied by a renewable energy system.

This development has set a very strong example for all local authorities in Ireland as to their capability to set energy standards beyond national standards. It also encouraged the national energy agency (Sustainable Energy Ireland) to review its own targets for the House of Tomorrow programme, a funding initiative for energy efficient housing. It forced building developers and other interested parties to actively deal with energy efficiency and renewable energies and to take a position on their ability and willingness to deliver houses that meet them.

Initially, the proposals were received with a certain degree of scepticism in the Council. The market response to such standards was first tested during discussions with a local developer, Menolly Homes, who wanted to develop land in the county. It has to be noted that a very large proportion of housing construction in Ireland is undertaken by developers i.e. companies who acquire sites and build multiple houses (sometimes by the hundreds) for sale or rent to householders. Thus, developers' response to the proposed standards was fundamental.

The Council put forward as a condition for rezoning the land that Menolly Homes sought to develop that the energy standards originally proposed for the County Development Plan should be achieved, and managed to receive a public commitment from the developer to comply. This gave sufficient confidence for the councillors to submit the following proposals into the Local Area Plan for Cappagh which were successfully voted through in October 2005:

"All new buildings will meet the minimum low energy performance standards (as defined below) as a prerequisite to receiving planning approval (calculation report to be submitted with the planning application). Each building's energy performance calculation must be demonstrated on the basis of a simple approved method (e.g. EN 832) carried out by qualified or accredited experts. Low energy buildings are defined as buildings with an annual heating requirement (space and water heating) not exceeding 50 kWh/m2 of useful floor area. The development will utilise renewable energy supply systems to meet at least 30% of the buildings space and water heating requirements as calculated on the basis of an approved method carried out by qualified or accredited experts." [3]

In December of the same year, Fingal County Council demonstrated that their intentions went beyond a one-off trial by voting the same building energy requirements into two other Local Area Plans (North Ballymun and Northwest Balbriggan).

While parts of the construction industry opposed the introduction of these standards, several companies welcomed it.

By June 06, Fingal County Council had also introduced energy standards in several other areas. Some of them include a performance based CO_2 Emissions Target (CET) which requires a reduction of at least 60% in CO_2 emissions deriving from energy usage for space and water heating within the housing development, relative to a baseline of prevailing regulatory and design practice. The 30% contribution of renewable energy systems to meet the collective space and water heating requirements within the housing development was maintained as a requirement in the standards.

Other counties (Dun Laoghaire-Rathdown County, and Dublin/Wicklow Mountain) followed the examples with analogous regulations. Meanwhile, more than 10% of the population of the Republic of Ireland live in counties that have approved a solar obligation.

In all cases, the local authorities require the submission of a report with the results of the calculations of the energy performance of the relevant building(s), as proof of compliance with the planning application. However, there doesn't appear to be any provision in the local planning regulations to check compliance at post-construction stage, nor is there an explicit plan for linking the enforcement of the local building energy standards with the building control system.

The rising tide of local building regulations triggered a discussion also at national level that is currently ongoing. A detailed report on the Irish regulations is available at www.estif.org/stap

Annex 6: Technical specifications for solar obligations

Solar obligations require a number of technical specifications, in order to:

- Define the required solar contribution
- Calculate and monitor its fulfilment
- Enable controlling procedures and sanctions

The reasons and arguments for setting these specifications are extensively discussed above in the chapters 3.3 (Quality assurance measures) and 3.4 (Structure and guidelines for solar obligations). This annex should be considered in light of the arguments above.
The coherence of these specifications is essential to guarantee that the solar obligations reach the desired results in terms of energy savings, and as a basis for the necessary quality assurance procedures.
Therefore, quantitative and qualitative requirements must be set on:

- The solar system and its components, both on the quality aspects and the system performance and output. These must be in line with European standards and certification procedures.
- The quality of the installation work carried out by qualified (trained, experienced and certified) installers
- Clear description and information to the user on installation / commissioning checks, system operating conditions and system + installation guarantees.

Scope of these recommendations

The following refers exclusively to solar obligations. In the voluntary market, also in case of financial incentives, it is not reasonable to set such strict requirements.

The following refers to domestic hot water (DHW) systems only. For the time being, it is not recommended to oblige the use of solar Combi-Systems (supporting domestic hot water and space heating), nor of solar assisted cooling or industrial process heat.

Definition of small vs. large systems

This distinction is defined on the basis of ISO 9459-5 and ISO 9459-2 – the test methods behind system Solar Keymark:

Small DHW systems is defined by:

- Collector area ≤ 10 m²
- AND tank volume ≤ 600 litres

Large DHW systems are all those not falling into the category of small, i.e. with:

- Collector area > 10 m²
- OR a tank > 600 litres.

General requirements on system size and performance

As all new buildings in the EU are covered by the EPBD (Energy Performance of Buildings Directive), an energy calculation shall in principle be performed anyway, and a calculation of the solar system should be included in this obligatory calculation.

The recommended requirement is that the calculated output of the solar system should be at least X% of the net hot water load used in the calculation. It is recommended that this minimum solar fraction, X is between 40 and 70% - depending on the available sunshine in the country/region. The method used for the calculation of the solar system performance should be based on the European standard EN15316-4-3.

The requirement should NOT be based on a minimum collector area, as this will favour bad performing collectors and will not sufficiently guarantee the energy output.

Minimum requirements on system and/or main system components

Case 1: Small DHW system

At least one of the following two sets of requirements REQ A/B should be fulfilled:

REQ A:

- System Solar Keymark (including performance figures)
- Tank volume bigger than the design value for the average daily draw-off

REQ B:

- Collector Solar Keymark
- Total tank volume bigger than the design value for the average daily draw-off
- Tank insulation better than corresponding to a heat loss coefficient of 1 W/K per m² tank surface [corresponds to e.g. 40 mm of mineral wool with a thermal conductivity of 0.04 W/(m*K)] and "thermal bridges" especially in the upper part of the tank should be minimised
- Heat exchanger area larger than 0,2 m² per m² of collector area
- Pipe insulation thickness ≥ outer pipe diameter, assuming a thermal conductivity of 0.04 W/(m*K) of the pipe insulation material. If thermal conductivity is lower, the insulation thickness can be reduced accordingly.

Case 2: Large DHW system

At least following sets of requirements should be fulfilled:

- Collector Solar Keymark
- Solar part of the tank volume must be bigger than the solar fraction X times the average daily draw-off (as used in "EPBD calculation"); the solar fraction X

is defined in "General requirements" above (values of X are between 0.4 and 0.7)
- Tank insulation better than corresponding to a heat loss coefficient of 1 W/K per m² tank surface [corresponds to e.g. 40 mm of mineral wool with a thermal conductivity of 0.04 W/(m*K)] and "thermal bridges" especially in the upper part of the tank should be minimised
- Heat exchanger area larger than 0,2 m² per m² of collector area
- Pipe insulation thickness ≥ outer pipe diameter (assuming a thermal conductivity of 0.04 W/(m*K) of the pipe insulation material; if thermal conductivity is less, the insulation thickness can be reduced accordingly).

Minimum requirements on installation/installers

Both for small and large solar DHW systems, a scheme for performing random sample inspections on installation by an independent body is recommended. This inspection scheme could be part of or connected to the scheme anyway required to check the requirements given in the Energy Performance of Buildings Directive (EPBD) related to:
- making energy certificates for the building
- inspection of boilers
- inspection of air-conditioning systems.

It is reasonable to perform random inspections more frequently on large systems than on small systems.

Case 1: Small DHW system

To avoid problems connected with the installations of small solar systems, the installers must know about solar systems and how to install them correctly, and the installer responsible for the installation must be defined. To assure this the following is recommended:

- Installers shall have a certificate or other proof of appropriate knowledge to install a solar DHW system. This could be a course of 1-2 days (including examination) about installing small solar systems.
- A filled in commissioning check list (as provided by the supplier as part of his guarantee) showing that the system is functioning and that all functions are tested and perform according to specifications must be delivered to the user together with the system. This check list shall also define the responsible installer by name, the system supplier, the installation company, contact data and signature.
- Apart from the supplier guarantee, the guarantee on the installation work of the collector shall be at least 5 years. For the rest of the installation work the guarantee shall be at least 2 years. This guarantee will cover all costs related to repairs. It is recommended to combine the guarantees above with a service

contract offered by the installer (e.g. including an annual service check of the system).

- A user manual must be delivered to the user together with the system giving instructions for operation and maintenance in the local language

Case 2: Large DHW system

The same as above, plus an additional course of 1-2 days (including examination) about dimensioning and installing large solar DHW systems.

Minimum requirements on function control

Case 1: Small DHW system

For small DHW solar systems it should be possible and simple for the user to check if the system is operating and delivering heat:

For pumped closed pressurized systems only:

A pressure gauge with indication of min/max level shall always be installed, and it shall be stated in the user manual, that the pressure meter should be checked by the user e.g. twice a year. The user manual shall state that if problems are suspected, first thing to do is to check system pressure. If pressure is below limit, refill system slowly and check for leakages. If pressure is above limit, call installer.

For drain-back systems only:

A fluid level indicator with indication of min/max level shall always be installed, and it shall be stated in the user manual, how and when to check the level. The user manual shall state that if problems are suspected, first thing to do is to check fluid level. If level is below limit, refill system slowly and check for leakages. If level is above limit, the installer should be called.

For thermo siphon systems only:

It shall be described in the user manual that in case of a suspected malfunction (which cause is not directly visible), first thing to do is to refill system slowly and check for leakages. If refilling is needed frequently, the installer should be called.

For all kinds of small DHW systems:

- How to refill system shall be described in user manual
- If a scald valve is installed, which needs maintenance (“regular manipulation”), the user manual shall clearly state how and when to do this .
- A procedure shall be described in the user manual how to check if the system is collecting/delivering heat. It should basically tell the user to check the temperature increase in the tank a sunny day having any supplementary heating turned off. If the temperature does not increase or increase only very little and refilling system does not help, installer should be called. The check procedure could look something like:

- *Check weather forecast: it should be a clear and sunny day above 0°C*
- *Start procedure approx. 7 am*
- *Turn off all auxiliary/supplementary heating connected with the solar system*
- *Draw off all hot water in the tank until outlet temperature is at least down to approx 5°C above cold water inlet temperature. This draw off shall be finished before 8 am.*
- *Be sure not to make any draw off's during the day*
- *Count the hours of full sunshine during the day, there should be least 4*
- *At around 6 pm, make again a draw-off of at least 10 litres.*
- *If the temperature of the water tapped has not increased at least 20°C (compared with the temperature tapped in the end of the morning draw-off), a system malfunction is possible and the system should be inspected by the installer.*

Case 2: Large DHW system

For large DHW solar systems it shall be possible for the user/installer to check a bit more in detail if the system is operating as expected:

- A pressure gauge (or in case of a drain-back system: a fluid level indicator) with indication of min/max level shall always be installed. It should be stated in the user manual that if problems are suspected, first thing to do is to check system pressure / fluid level. If level is below limit, refill system slowly and check for leakages. If pressure is above limit, call installer.
- How to refill system shall be described in user manual
- A simple function control alarm device[3] shall be fitted to the system, giving alarm (red light / beep sound) if e.g.:
  - *pressure / fluid level below/above limits: Recommended actions are given above*
  - *collector temperature > tank temperature + 50°C: Recommended action: Call installer.*
- If a scald valve is installed, which needs maintenance ("regular manipulation"), it shall be clearly stated in the users manual how and when to do this.
- Thermometers showing the temperature in the lower 3rd and the upper 3rd of the tank shall be fitted.
- A display showing the collector sensor temperature shall be fitted.
- A monitoring device[4] showing on a display the instant thermal power delivered from the collector loop shall be fitted to the system. It shall be described in the user manual how to check if the system is collecting/delivering the minimum expected thermal power. An example of a check procedure is given here below:
  - *At a clear and sunny day at a point in time of the day when the sun shines at maximum at the collector plane (the angle between the normal to the collector plane and the direction to the sun shall be in the interval 0° ± 30°) read the displayed power and the temperature of the collector sensor. Read/estimate also the outdoor air temperature. Be sure that no clouds or shadows appear.*

[3] For pumped systems, this function control could be integrated in the solar system controller.
[4] For pumped systems, this monitoring device could be integrated in the solar system controller.

Compare power read with the minimum expected power given in the user manual.(see next paragraph: "Determination of minimum expected power, P_{min} guidelines").

- *Note: This simple check procedure is to be seen as a function control. It can not check very accurate if the system is exactly performing according to specifications as the irradiation and collector temperature during the test are not measured, but it will say if something is wrong.*

It is of course possible to use more advanced/accurate check/monitoring equipment/procedures including e.g. continuously recording of the irradiation and the relevant temperatures in order to give alarm if expected minimum performance is not reached. For very large DHW systems (> 100 m²) it is highly recommended to require the use such more advanced automatic surveillance equipment as e.g."I/O-C"[5] (input/output control).

Determination of minimum expected thermal power, P_{min} guidelines

P_{min} should be given in the user manual in e.g a table like the one below, showing the temperature limits of the procedure:

Temperature difference: Collector temperature - outdoor air temperature	P_{min} in kW
Below 60 K	**P_{min} value**
Above 60 K	Method not valid

P_{min} can be determined in the following way:

$P_{min} = F_{loop} * P_{700,50}$ / 1000 [kW], where:

- $P_{700,50}$ gives the expected output of the collector at a solar irradiation of 700 W/m² and 50 K difference between collector and ambient air. The value of $P_{700,50}$ is given in the power table in the test report according to EN12975-2 and should be stated in the user manual.
- F_{loop} is a penalty factor to compensate for heat losses in collector loop. F_{loop} = 1 corresponds to no heat losses in collector loop and a constant irradiation of 700 W/m² and a constant temperature difference between average collector fluid temperature and outdoor air temperature of 50 K.

F_{loop} can be calculated as: $F_{loop} = S * [N*P_{700,50} – UA_{pipes}*T_{dif}] / [N*P_{700,50}]$

- S: Security factor taking into account uncertainties in the procedure = 0.8
- N: Number of collectors
- UA_{pipes}: Heat loss coefficient of the collector loop piping
- T_{dif}: Temperature difference: Collector temperature – outdoor air temperature; use 60 K

Using S = 0.8 and T_{dif} = 60 K the equation for F_{loop} becomes:

$F_{loop} = 0.8 - 48*UA_{pipes} / [N*P_{700,50}]$

In almost all cases (except when extremely long pipe length / badly insulated piping combined with a low efficiency collector) F_{loop} will be bigger than 0.5. So if the calculations above are not performed, a dummy value of 0.5 for F_{loop} can be used:

[5] An "I/O-C", input/output control device continuously check whether the output delivered corresponds to value expected at the actually operation conditions (solar irradiation, temperature level, etc.)

$F_{loop,dummy}$ = 0.5

Example

Collector array power

- $P_{700,50}$ = Collector power at 700 W/m² and 50 K = 600 W (given in test report)
- N = No. collectors = 10
- $N*P_{700,50}$ = 6000 W

UA_{pipes}

- Total length of pipes = 30 m
- Heat loss per meter = 0.2 W/(K*m)
- Other heat losses in collector loop = 2 W/K (to be estimated based on number of un-insulated parts of the collector loop such as: pump, security valve, other valves, etc.)
- UA_{pipes} = 30*0.2 + 2 = 8 W/K

F_{loop}

- F_{loop}= 0.8 – 48*8 / 6000 = 0.8 - 0.064 = 0.74

P_{min}

- **P_{min}** = 0.74 * 6000 / 1000 = **4.4 kW**

(using the dummy value of 0.5 for F_{loop} gives P_{min} = 3 kW)

This simple check procedure is to be seen as a function control. It can not check very accurate if the system is exactly performing according to specifications as the irradiation and collector temperature during the test are not measured, but it will say if something is significantly wrong.